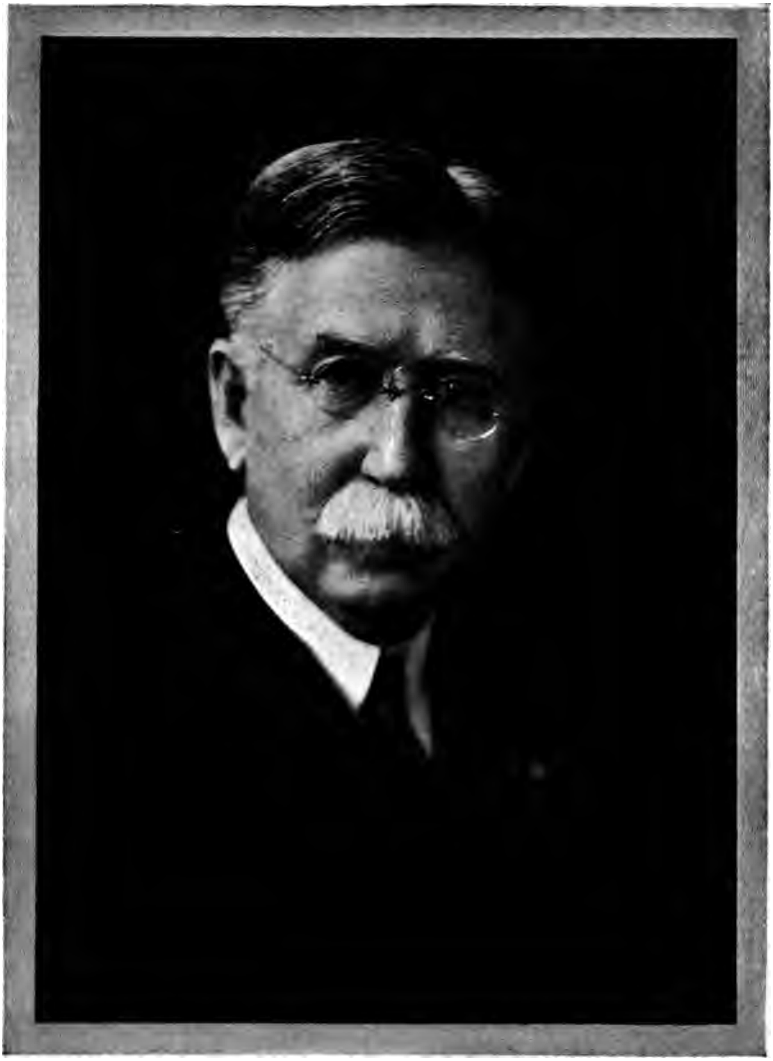

MR. EDWARD L. DOHENY, PRESIDENT.

Mexican Petroleum

J. S. ROSS

Description of properties of the

PAN AMERICAN PETROLEUM & TRANSPORT COMPANY (*Feb. 2, 1916*)

and principal subsidiaries

MEXICAN PETROLEUM COMPANY (CALIFORNIA) (*Dec. 20, 1900*)

HUASTECA PETROLEUM COMPANY (*Feb. 12, 1907*)

MEXICAN PETROLEUM COMPANY, LIMITED, OF DELAWARE (*Feb. 16, 1907*)

MEXICAN PETROLEUM CORPORATION (*May 17, 1915*)

THE CALORIC COMPANY (*March 21, 1916*)

PAN AMERICAN PETROLEUM COMPANY (*Sept. 11, 1916*)

MEXICAN PETROLEUM CORPORATION OF LOUISIANA, INCORPORATED (*Feb. 5, 1918*)

BRITISH MEXICAN PETROLEUM COMPANY, LIMITED (*July 15, 1919*)

and other Data.

Published by the

PAN AMERICAN PETROLEUM & TRANSPORT COMPANY

NEW YORK, 1922

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DETAILED CONTENTS

SUPPLEMENTARY DATA

N. B.—The material on pages 283, 285, and 287-290 is taken from Mr. J. R. Battle's book on "Industrial Oil Engineering" published by J. P. Lippincott Company, to whom thanks are given.

LIST OF ILLUSTRATIONS

PREFATORY NOTE

THE MANAGEMENT desires to express its appreciation of the care with which *the Editor,* Mr. W. J. Archer, a member of our organization, has collected the material for this book, and the manner in which it is presented.

The entire volume was written by him with the exception of the Address by the President, Mr. Edward L. Doheny, which forms Chapter II, and some technical matter incorporated in other chapters. Every facility was afforded him to obtain information and verify statistics, and to examine *all* the properties of the Company.

We endorse this work, confident that its readers will find it a source of reliable and useful information not only in regard to our own properties, but also on the more general aspects of the petroleum industry.

PAN AMERICAN PETROLEUM & TRANSPORT COMPANY.
120 BROADWAY, NEW YORK.

FOREWORD

THE primary purpose of this volume is to supply information in reference to the development of the *Pan American Petroleum & Transport Company* and its chief subsidiaries, and the activities of these Companies in both hemispheres. The book contains a survey of the vast areas of productive oil land in Mexico and California, with hundreds of miles of pipe lines and many pumping stations; a short account of refining and the refineries at Tampico and Destrehan; details in reference to the transportation of oil both by land and sea, and the facilities that the Company has for supplying the largest ocean-going steamers with fuel oil at numerous ports in North and South America and Great Britain. To this has been added a chapter on the geographical distribution of petroleum, and information and tables which it is hoped will be useful to engineers and others engaged in the oil industry.

The assistance, so willingly given by all associated with the Company, is very highly appreciated. The editor wishes to express his thanks to the heads of departments for their co-operation, and to those whose specialized knowledge of the Company's work has been invaluable.

Some of the photographs reproduced have been kindly lent by the Bureau of Mines, the U. S. Geological Survey, the Pan American Union, the Oil Well Supply Company, the National Supply Companies and Mr. H. A. Franck.

Many books have been consulted and the editor acknowledges gratefully help from the following: *Geology of Petroleum,* by W. H. Emmons; *American Petroleum Industry,* by R. F. Bacon and W. A. Hamor; *Practical Oil Geology,* by D. Hager; *Das Erdöl,* by Engler und Höfer; *Mechanical Engineers' Handbook,* by Lionel S. Marks and others; all published by the McGraw-

Hill Book Company; *Industrial Oil Engineering,* by J. R. Battle, published by J. B. Lippincott Company; *Oil-Field Development,* by A. Beeby Thompson; *Fuel,* by J. S. S. Brame; *Petroleum and Its Products,* by Sir Boverton Redwood; *Oil Finding,* by E. H. Cunningham Craig; *Text-book of Geology,* by L. V. Pirsson and C. Schuchert; *The Oil Conquest of the World,* by F. A. Talbot; *History and Romance of the Petroleum Industry,* by J. D. Henry; *The Petroleum Handbook,* by S. O. Andros; *Oil Tank Steamers,* by Capt. H. J. White; *Petrol and Petroleum Spirits,* by W. E. Guttentag; and numerous bulletins from the U. S. Geological Survey and the Bureau of Mines.

Since this volume went to press, an interesting book has been received on the *Economics of Petroleum,* by Joseph E. Pogue. The author has a chapter entitled "Mexico as a Source of Petroleum," which contains an estimate, in the form of a chart, of the unmined supply of crude petroleum in that country. The ink could scarcely have been dry on this chart before an important section of it was proved to be erroneous, which does not enhance the value of the remainder. Mr. Pogue gives a table, on page 324, based on the estimates of Mr. Ralph Arnold, which states that "the proven oil reserve of Mexico at the end of 1920 is between three hundred and four hundred millions of barrels." In 1911 Mr. Arnold valued the properties of this Company in Mexico at $9,438,000, truly a modest sum, seeing that during a single month, December 1921, 7,524,438 barrels of oil were taken from the Company's wells. If Mr. Arnold's present-day predictions be read in the light of his predictions of ten years ago, it will be evident that undue confidence need not be placed in his methods or figures. Mr. George Otis Smith, Director of the U. S. Geological Survey, puts "the proved area of Mexican oil fields at about 10,000 square miles, with resources of 4,500,000,000 barrels, and the potential output of unproved territory at 1,250,000,000 barrels, a total estimate of 5,750,000,000 barrels, or a supply adequate for forty-five years at the 1920 rate of export."

THE EDITOR.

New York,
May, 1922

MEXICAN PETROLEUM

Mexican Petroleum

CHAPTER I.

INTRODUCTION

THE RECENT war has done more to arouse interest in petroleum than a decade of the most intensive advertising. Throughout every country in the world today, the search for oil is being pursued with keenness and diligence by men who have the necessary knowledge, and who are stimulated in their work by the universal recognition of its value and indispensableness in the complex and varied activities of modern industrial and social life.

There is a romance about obtaining rare and valuable products hidden within the earth's crust; and the search for them in lands untouched by civilization acts as a lure which cannot be explained alone by the material rewards attending success. Prospecting in new countries appeals to man's love of adventure, with its accompanying soupçon of danger. It appeases to some extent his craving for novelty, and exercises those speculative proclivities which are a part of nature's endowment of the men whose biographies are never dull. Men of foresight who are planning the world's future, realizing the paramount importance of oil for commercial and industrial developments, are giving every encouragement to investigators who will undertake research work in countries hitherto unexplored.

The value of oil no longer needs proof. During the war it was used in the manufacture of high explosives; and the movement of trucks, ambulances, lorries, tanks, guns, aeroplanes, submarine chasers, motor boats and battleships was absolutely dependent on it.

The uses of oil in days of peace are no less important and no less varied than in the critical hours of war. The proof of this

needs no demonstration, and the world no longer asks "Is oil useful?" but "Where is it to be obtained?"

A recapitulation of the various theories regarding the origin of oil is foreign to the purpose of this chapter. The question is still surrounded with the stimulating atmosphere of discussion, and there is little indication that the protagonists of organic and inorganic theories are reaching a definite basis of agreement. It is not to be assumed that the question of its origin is considered unimportant; a correct theory would form a valuable guide to a better understanding of the migration and accumulation of petroleum.

It is a long and interesting story from the days in which oil was supposed to have been vomited by the eagle that devoured day and night the liver of Prometheus, to the latest geological or chemical theory; and those who wish to study the subject will find it elaborated in the more important text-books. From the point of view of immediate industrial developments, the primary question is "*Where* is oil to be found?" *Whence* it comes, is a subject for the chemist and geologist.

References to petroleum are found in Greek, Latin, Babylonian, Chinese and other literatures. The Incas of Peru and the Aztecs of Mexico employed bitumen in their architecture and works of art; so that literally from China to Peru petroleum has been known to exist for ages.

The widespread occurrence of petroleum is indicated by names of places scattered throughout the world. We have Pitchford in England, Petrolea in Canada, Chapopote in Mexico, Pechelbron in Germany, Yenangyaung in Burmah, and the prefix "Kir" in many places in Persia, proving the early observation of petroleum.

Oil has become so essential to industry and commerce that the question of its distribution is of engrossing interest and increasing importance. We have had recently many pronouncements assuring us that oil in some countries is within measurable distance of exhaustion. Prophecies in regard to events in 1940 have all the advantage of being safeguarded from effective

contradiction; but a very shrewd poet, who died millenniums ago, bequeathed to us the pithy saying, "Forecasts of the future are doomed to blindness," and many statements about petroleum made a few years ago show the peril of forecasts.

The discovery of the manifold uses of oil is very recent. The honor of tapping the source of it by drilling is due to an American, Colonel E. L. Drake; whilst the distillation of oil from shale is the work of a Scotchman, James Young.

We shall take these discoveries in their chronological order. Near Alfreton, Derbyshire, in the Riddings Colliery, oil was found oozing from the shales in 1849, the residuum of which after distilling off the more volatile portion was used as a lubricant for machinery. Hitherto, lubricants had been artificially prepared from vegetable and animal materials; and James Young, who had devoted some time to the study of chemistry, stimulated by the idea of obtaining an adequate supply of this new lubricant, conceived the idea of distilling the shale. Experiments proved that some of the Scotch shales yielded very satisfactory results. At that time, the lighter portions were regarded as a waste product, but later it was discovered that these waste products were being burned in specially constructed lamps in Germany, and this became an important factor in the development of the domestic uses of oil for lighting purposes. In 1850 James Young took out a patent for the production of paraffin by distillation, and this marks the beginning of the exceedingly complex industry which is conducted in our modern refineries.

The discovery of oil by drilling, which was made in 1859 by Colonel Drake began a new era in the history of petroleum. The early white settlers on the American Continent became acquainted with petroleum first of all through the Indians who had known of its curative properties from time immemorial, and for more than a century it was called "Seneca oil." During many years, this was collected by soaking flannel rags with the oil which formed a scum on the surface of the swamps and ponds of Pennsylvania, and wringing them out. The oil obtained in this way was sold as an antidote to certain maladies by vendors

in New York. After many praiseworthy but unsuccessful attempts to discover the source of oil, Colonel Drake in 1859 began his work with a grim earnestness and determination which was ultimately crowned with success. He chose a spot on Oil Creek, Pennsylvania, in a picturesque, sylvan valley, through which flows a beautiful stream. This quiet dale is sheltered by gradually ascending hills, and on its floor Drake sunk his historic well. The tools used by him compared to our elaborate modern equipment were of the most primitive type. He commenced operations on May 20, 1859. One of the perils of modern drillers beset him early, and he was forced by an inrush of water

PIONEER WELL IN THE UNITED STATES—1859.

to desist. He then decided, in order to shut off the water, to drive a pipe into the ground until it rested on the solid rock. His "boss" driller was "old Billy" Smith, and these pioneers, who "builded better than they knew," were after much toil and many disappointments rewarded with success. In August (the exact date is in dispute) 1859, at a depth of over 69 feet, petroleum was seen to be rising at the mouth of the bore-hole. It was the first strike of oil in history, and destined to be the beginning

of one of the most important and necessary industries of modern life. It is no exaggeration to say that, without oil, the machinery of the whole world would be brought to a sudden pause, for our complex life is largely dependent on the discovery made by Colonel Drake in this remote valley.

IN MEMORY OF COLONEL DRAKE, NEAR SITE OF PIONEER WELL.

The first oil well yielded 20 barrels a day, and aroused unparalleled interest. This well heralded a complete change at Oil Creek, and within an incredibly short time it was transformed from a peaceful country scene into a populous city of the most intense activity and frenzied excitement. The story of Oil Creek is a combination of comedy and tragedy with few parallels, but it marks the beginning of an education in oil production which ultimately gave the mastery to the United States. Neither

daunted by colossal failures, nor enervated by rapid bewildering successes, the oil producers of the United States have raised the output from 20 barrels a day in 1859 to 469,639,000 barrels a year in 1921.

Of all the riches obtained from the earth, omitting the foods produced from year to year, iron is the one product which can rival petroleum in the manifold and varied uses to which it may be converted. If we take into consideration shales, natural gas, and asphalt deposits, petroleum is one of the most widely distributed of all natural substances. The word "petroleum" is derived from the Latin "petra," rock, and "oleum," oil. Formerly oil was supposed to be derived from coal; but coal-oil is oil distilled from bituminous coal. The term, properly speaking, is not synonymous either with petroleum or with illuminating oil produced from petroleum. Many of the names employed today to designate the various products of crude petroleum are of a more or less arbitrary character.

Petroleum is obtained from shales, natural gas, and asphalt deposits, as well as being found in the fluid state, and this latter is the most important of the forms in which it exists. It is sealed in certain rocks, and the oil-bearing strata are discovered by the drill. The popular idea of "reservoirs" of oil, or "underground lakes," needs modification. The huge gushers in Baku, and the unparalleled output of large flowing wells in Mexico have given color to the idea of vast caverns where oil is stored. The formations containing the oil are known as "reservoir" rocks, which are porous, and *these pores provide storage for the oil.* The principal requisites necessary for a productive oil-field consist of a coarse-grained "reservoir" rock, overlain by a practically impervious cover, which is generally limestone or shale. The rock overlying the "reservoir" rock is often alluded to as the "cap" rock. The "reservoir" rock is also underlain by one of such close texture as to prevent the oil from escaping. Were it not for compact, overlying beds, either the volatile oils would escape, or water would flood the oil strata; and the impervious rock *beneath* is necessary to seal the oil in the "reservoir" rock.

E. R. Buckley in his "Building and Ornamental Stones of Wisconsin," gives an interesting table on the effective porosities of various stones which he tested. From 14 samples of granite the average porosity was .332; 11 samples of limestone gave an average of 4.43; and 16 of sandstone showed the high average of 14.46. It is obvious, therefore, that the possibility of oil reservoirs in igneous rocks like granite is very slight.

An oil reservoir may be defined as a system of intercommunicating spaces of such diameter and so connected as to yield oil to a hole penetrating it. The best reservoirs for oil are coarse sands, conglomerates, and porous dolomitic limestones. Porosities vary very greatly in oil-bearing strata. "Sands may contain from 15% to 25% voids; sandstones, 5% to 15%; conglomerates may contain as high as 30%; shales from 2% to 10%; and some dolomitic limestones are reported to contain as high as 35% voids." To explain the porosity of rocks, a crude illustration will suffice. A quart vessel may be completely filled with No. 8 shot, and still be capable of holding a considerable quantity of water. Some rocks in which oil is found might be compared to a sponge. This is especially true of limestones where dolomitization has taken place. "Oil sand," which is a term in general use in the fields, is not necessarily sandstone; for example, the "oil sand" at Petrolea, in Ontario, is porous limestone.

Petroleum is not a definite chemical compound. It is an extremely complex mixture of a series of hydrocarbons—combinations of hydrogen with carbon—the number of the members composing which, as well as their respective proportions, varying according to the district in which the oil is found. It also contains many widely different substances in small amounts, whose exact nature is not always clearly defined. In appearance, oil varies in color from water-white, through amber, to brown and black—the black being most common. The smell of some oils is pleasant; others have a decidedly disagreeable odor.

One of the most important properties of petroleum is its volatility. The lighter products escape when exposed to the air, in the form of vapor or gas, and the residue gradually becomes

denser and denser, until it reaches a solid state, when it may form a natural asphalt road, as may be seen in the interior of Mexico. Upon the volatility of oil depends the whole process of refining, the purpose of which is to separate it into its many valuable products. From the viewpoint of the petroleum refiner, crude petroleum is of two general classes or types, namely, those petroleums which carry little or no asphalt and which are termed "paraffin base," and those which yield practically no solid paraffin but are rich in asphalt and are called "asphalt base" petroleum. Strictly speaking, however, there is still another class known as paraffin-asphalt, semi-asphalt, or mixed-base petroleums, typified by certain of the crude oils from Illinois, Kansas, Oklahoma, and northern Texas, which contain both paraffin and asphalt, and are therefore a combination of the two other classes. The gravity of these oils ranges between those of Pennsylvania and California; their yield of gasoline is greater than that of the "asphalt base" oils, and less than that of the "paraffin base" oils. Oils are frequently referred to as "light," or "heavy," the lighter oils having a paraffin base and the heavier oils an asphalt base. The scale used in determining the weight of oil is the Baumé hydrometer scale. Water on this scale ranks as 10° and most oils are lighter than water.

Everyone is acquainted with the names naphtha, kerosene, gasoline, machine oil, paraffin wax, and asphalt, but the products of oil are difficult to define. Crude petroleum has varying characteristics according to the fields where it is found, and differences are often observed in the same well. Gasoline proper is sometimes called motor spirit, petrol, essence, etc., and has often like charity, been used "to cover a multitude of sins." The term is, of necessity, flexible, though restrictions are tending to standardize it.

The points of distillation of different products change with the demand. In tables published ten years ago, what was then designated naphtha is now sold as gasoline; while years previously, it formed a part of kerosene. In the early days of the use of oil, kerosene was considered dangerous, and this was due to the pres-

ence of constituents that are now contained in gasoline, which were then regarded as of little value. *Naphtha,* which is called *petroleum spirit* in Great Britain and *benzine* on the European Continent, is a general name covering all the more volatile products of crude petroleum. *Gasoline* which is known as *petrol* in Great Britain and as *essence* on the European Continent, is the most familiar of all the lighter products obtained from crude petroleum, and is used as fuel; for example, in the internal combustion engine of an automobile.

Gasoline, or petrol, is obtained by the following methods:

1. Distillation from crude petroleum.
2. ''Cracking'' of the heavier petroleum distillates.
3. Condensation from casing-head gas.
4. Distillation from shale oil.

The uses of petroleum are very numerous, and these have been summarized briefly in the ''World Atlas of Commercial Geography,'' published at Washington in 1921.

''Petroleum is used chiefly as a source of power, light, and lubricants, and these are the uses that everyone knows. Crude petroleum is used in decreasing quantities from year to year; more and more of it is prepared for higher utilization by breaking it up into refined products of greater value. The number of these refined products is almost countless, and their uses are as various as the needs of mankind. The light-gravity ethereal products are employed as local anesthetics. The gasolines are the universal fuels of internal combustion engines. The naphthas are extensively used as solvents and are blended with raw casing-head gasoline to make commercial gasoline. The kerosenes, though used chiefly for illumination, are employed in increasing quantities as fuel for farm tractors. The lubricating oils and greases are indispensable to the operation of all kinds of machinery. The waxes derived from petroleum of paraffin base are utilized in many forms—as preservatives, as sources of illumination, and as constituents of surgical dressings made for the treatment of burns. Petroleum coke, an almost pure carbon,

is used in metallurgy and in making battery carbons and arc-light pencils. Fuel oils obtained as by-products in refining petroleum are used for generating power by industrial plants, railroads, and ocean steamers. Road oils are employed to lay the dust on streets and highways, and artificial asphalt a product of petroleum, has in some places been used for paving.''

The petroleum industry is one of the most romantic in the whole field of commerce. It is often marked by harassing delays and disappointments during the early stages, followed by successes and rapid expansion when land is proven to be rich in oil. These features are well illustrated by the history of the Pan American Petroleum & Transport Company, and its subsidiaries, which is the subject of the major portion of this book.

TAMESI RIVER, TRIBUTARY OF THE PANUCO, MEXICO.

CHAPTER II.

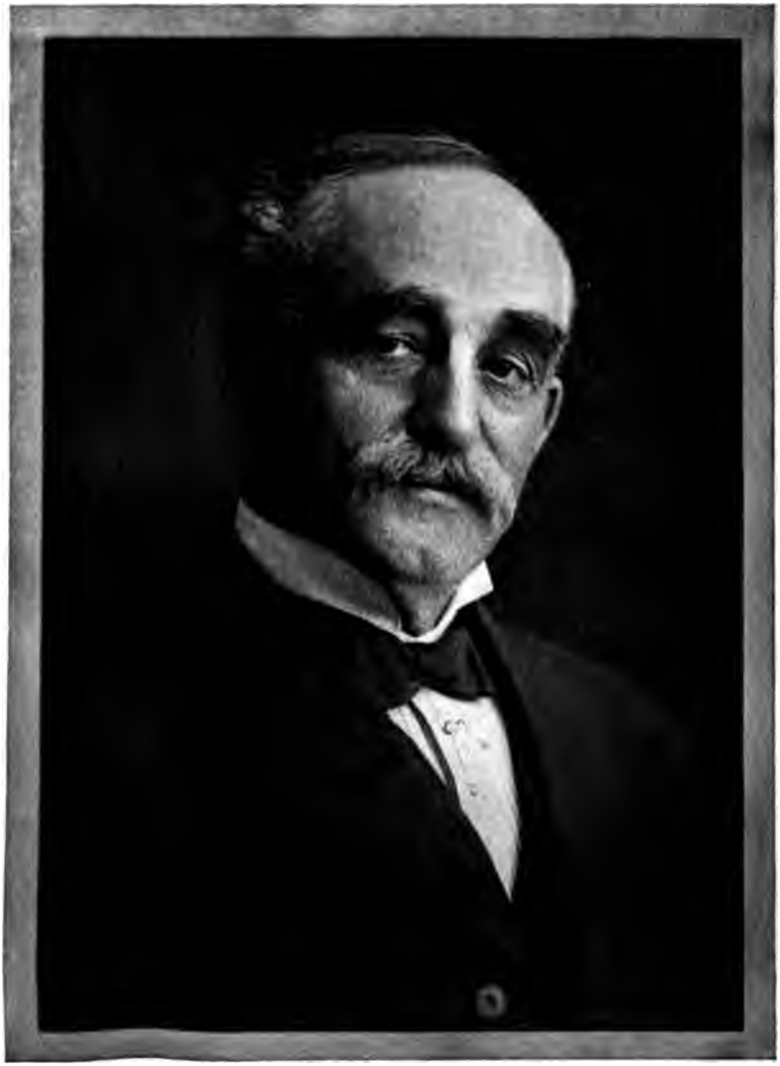
HISTORY AND FUTURE OF THE OIL INDUSTRY IN MEXICO*

OWING to the comparatively recent discovery and development of oil in Mexico, it is justifiable, in judging of its future, to give close consideration to the history of its past. For me to write such a history a largely personal narrative seems unavoidable.

It is now nearly twenty-two years since I made my first prospecting trip to Mexico, looking for oil lands. It is ten years since the developments which were made by our companies attracted the attention of the oil world by the bringing in of one of the greatest wells in oil history. During these ten years the vicinity of that remarkable development has been the scene of extraordinary activity, where a hundred companies, with scores of thousands of employees have performed every kind of work necessary in the exploitation of a most extraordinary field, which, being divided into comparatively small tracts of land, gave many independent developers an opportunity to share in the great discovery.

Opinions as to the future of the oil industry in Mexico are as diverse as the number of individuals who, with more or less local and general knowledge, express them. Being the first to develop oil successfully in Mexico, and having formed very decided views before beginning exploitation, though without any knowledge of the prospectivity of the region, except such as was ascertainable by a close study of the surface and geological con-

* An Address by MR. EDWARD L. DOHENY, delivered at the Second Annual Meeting of the American Petroleum Institute, held at the Congress Hotel, Chicago, Dec. 6, 1921.



THE LATE MR. C. A. CANFIELD.

ditions, I assume that the opinions which I early formed, and still hold, and which time alone will corroborate or disabuse my mind of, will be of interest to you.

Pioneering in Mexico—In May, 1900, C. A. Canfield, a well known and successful oil prospector of California, and A. P. Maginnis, a prominent railway official of that State, with myself, made a trip to Mexico at the suggestion of the late A. A. Robinson, the then president of the Mexican Central Railway Company, who had hopes of seeing oil developed somewhere near the line of his railroad.

Although we then and always before considered ourselves prospectors, we had really graduated from that very worthy and energetic class of men to whom our great West owes so much. We were not under the necessity of being "grub-staked" by anyone, or of carrying our whole belongings on the back of a burro, or more ostentatiously on the hurricane deck of a cayuse. Our previous success in finding oil in California led to our going on this prospecting trip in a private car, traveling with passes issued to us because of the benefit which it was supposed the Mexican Central Railway Company might gain from our success.

Two thousand miles by rail we journeyed from Los Angeles to Cardenas in the eastern part of the State of San Luis Potosi, there reaching the edge of that great descent where the railroad plunges from the central mesa of Mexico down over the upturned Tamasopo limestone formation, whose uptilting has created a gigantic barrier wall several thousand feet in height and several hundred miles in length, forming the eastern declivity of the Cordillera del Oriente of Mexico. Beneath this wall there stretches out to the coast that great plain known as La Huasteca, which is covered with dense, tropical vegetation due to the warm weather and enormous rainfall of that region.

To prospectors who were accustomed to the balmy atmosphere of the Rocky Mountain ranges and the Pacific Coast of Southern California, the trip from El Paso for over a thousand miles down to this jumping-off place, showed little climatic change.

The descent into La Huasteca Potosina, however, brought us into a country with which we were entirely unfamiliar. We were filled with misgivings as to the success of our trip.

Active Oil Exudes—If it was the purpose of this address to describe the country which we penetrated, an interesting picture might be drawn of the beautiful and somewhat awe-inspiring scenery which is met with on the railroad going down through the Tamasopo cañon, making a drop of five thousand feet in less

SCENE ON TAMESI RIVER, TRIBUTARY OF THE PANUCO.

than thirty miles, on a railway track which skirts the side of the cañon, tunnels the backbones of various ridges, making hair-pin turns which suggest catastrophe, down past rivers of clear blue green water; past the falls of Micos, where the leap of the water to where it falls in a mass of white foam is over 270 feet; down over the Taninul bridge where the Choy River flows out of the subterranean channel or natural tunnel in the rocks over two hundred feet below; and for a short space one sees only the skies before plunging into a forest so dense that it is hidden almost completely as it wends its way through the jungle to the Panuco, thence to the sea; down by Valles and out onto the rolling,

jungle-covered country which extends clear to the harbor of Tampico.

While greatly interested in the scenery, we were not inspired with much enthusiasm at the prospect of undertaking to develop oil in this far away and strange region where the climatic and other obstacles seemed great enough to deter one from even undertaking to mine gold, much less to discover oil, which would mean only the beginning of obstacles to be surmounted before a market could be developed that would justify exploitation.

We journeyed to a place about thirty-five miles west of Tampico where oil springs existed. A guide conducted us to two active oil exudes—one about three miles north of the Mexican Central Railway station, Chijol, and the other about five miles south of the station known as Auza.

At the latter place we found a small conical-shaped hill known as Cerro de la Pez, where bubbled a spring of oil, the sight of which caused us to forget all about the dreaded climate—its hot, humid atmosphere, its apparently incessant rains, those jungle pests the pinolillas and garrapatas (wood-ticks), the dense forest jungle which seems to grow up as fast as cut down, its great distance from any center that we could call civilization and still greater distance from a source of supplies of oil well materials—all were forgotten in the joy of discovery with which we contemplated this little hill from whose base flowed oil in various directions. We felt that we knew, and we did know, that we were in an oil region which would produce in unlimited quantities that for which the world had the greatest need—oil fuel.

Purchase of Potential Oil Lands—This visit was made before the days of automobiles. What we thought we knew was less than half of what was promised. Beaumont was to be discovered the next year, and all of the great fields of our Mid-Continent region, Kansas, Oklahoma, Texas, Arkansas and Louisiana were yet to be found. The nearest oil well supply station was Pittsburgh. Our market seemed to be the railways and industries of America, and all of the shipping of the world which might be bunkered at Tampico Harbor and other seaports.

OIL EXUDE AT BASE OF CERRO DE LA PEZ, EBANO.

Of course, we bought the ranch (Hacienda del Tulillo) upon which this hill was situated, and, of course again, we bought the ranch adjoining to the east, the Hacienda of Chapacao, upon which we found other substantial exudes north of Chijol station. We explored the regions to the north, south, east and west. Within a very few months we had penetrated the jungles, crossed the rivers and traversed the ranges of the country to the north as far as the Sota la Marina River, finding

OIL SEEPAGE IN SOUTHERN FIELDS.

many places of similar promise to Cerro de la Pez and Chijol. We went up the Panuco River and visited the seepages which have since been the scene of the great development known as the Panuco and Topila oil districts, going as far as the Tempoal seepages. We went to the south and visited San Geronimo, Los Higueros, Monte Alto, Chinampa and other lands further to the south. And we purchased Los Higueros and Monte Alto—properties upon which were substantial exudes.

The question naturally arises on what did we base our belief that there was oil to be found in commercial quantities in this region, seldom if ever before visited by oil prospectors. The Cerro de la Pez, as well as Chijol, with their active exudes, the gas continually coming to the surface, the hill of material different from that of the surrounding country, the evidence of oil oozing along the contact between the formations of which the hill was composed and the sedimentary formations which abutted against it, the exposures of the strata along the railroad cuts from the mountains down to the vicinity of these exudes, giving evidence of the nature of the rock formation for many thousands of feet in depth—all led us to the inevitable conclusion that this oil found its home or origin either in the upper surface of the Tamasopo limestone or in the more thinly stratified limestones and shales overlying it, and that these exudes merely marked the places where the Choy formation, or Mendez shales, were fractured and dislocated so as to permit the flow of the oil to the surface.

Oil, being a liquid, is subject to the same influences whether the original oil-containing rocks are strata of porous sand formations as in California, or the honeycombed thickly-bedded limestones, as here in Mexico. The pressure of the superincumbent strata, capillary attraction, gas pressure and hydrostatic pressure all tend to draw or force the oil from its original receptacle upward to the surface along every line of least resistance, here, as well as on the Pacific coast. And here in Mexico the evidence was convincing that the conditions were favorable for the storing of immense quantities of oil.

Locating the First Well—We got maps and guides and made extensive excursions through the country, acquiring lands wherever possible, surrounding the most promising oil exudes. The amount of our acquisitions before any well was completed was 450,000 acres in fee. Our companies afterward acquired other lands, making in all 600,000 acres, which we still hold.

Our first well was located in March, a derrick built and the tools commenced to drop on the first of May, 1901. On the

fourteenth day of May we were awakened early in the morning by the driller, who told us that at the depth of 545 feet, oil had come into the hole in such quantity as to lift the tools off the bottom and interrupt drilling. He immediately put out the fire under the boiler and shut down, to await daylight and our inspection.

Attempts had, in the past, been made to discover oil in paying quantities in Mexico. Everywhere these efforts were unsuc-

GENERAL VIEW OF CAMP AT EBANO.

cessful. No drilling had ever been done, however, north of Cerro Viejo, which lies about eighty-five miles south of Tampico. The territory in which we began our development was virgin.

Our attorney, the late Pablo Martinez del Rio, told us that if the oil business was not being carried on in the Republic, we were entitled, under the law, to a permit from the Department of Fomento, to import, free of duty, goods necessary for the business; and to be otherwise freed from taxation except the stamp tax, for ten years. He proceeded to get us such a concession. In order to accomplish this, he had to file with the

Department of Fomento a declaration from the Governor of each State and Territory of Mexico that the petroleum business was not being carried on in his jurisdiction. There was no difficulty in getting this declaration from the Governors of every State and Territory except one. The Governor of Vera Cruz claimed that efforts had been made to get oil in his State, at El Cugas (now Furbero); at Chapopote Nuñez near the Tuxpam River,

SCENE ON TUXPAM RIVER.

and at Chapopotal, a hill on the hacienda of Cerro Viejo. An investigation, however, showed that the efforts in these places had been abandoned many years before, and our concession was granted.

Purchase of Private-Owned Lands—At this time there were no known public lands in this part of Mexico. All the vacant, unclaimed lands were called "terrenos baldios" or "vacantes," and were merely unclaimed, formerly private lands, the titles to which may have reverted to the government. Our purchases

were all made of privately owned lands. Our dealings were all with the owners or the administrators of the lands. I mention this because there is an impression abroad that the foreign oil land holdings in Mexico were acquired through concessions from the government—concessions of doubtful validity. Such an impression is absolutely erroneous, as all of the lands of all of the American companies, so far as I know, were the private property of individuals or of estates or "congregaciones."

In 1887, Mr. W. A. Goodyear, then Assistant State Geologist of California, made a very exhaustive study and report on all the oil exudes of that State. It can scarcely be credited that he knew the significance of the information which his annual report conveyed to the experienced prospector. That report, made some years before I went into the oil business, was really my best guide in the discovery of the various oil districts which it was my good fortune to open up in that State. Mr. Goodyear visited and described nearly every oil exude to be found in the entire State without ever undertaking to make any development of oil for himself.

The early map makers of the coastal plain of Mexico not only named every stream of importance, each one of the multitude of towns where the Indian population of this region had been collected for centuries, the haciendas where the large landowners made their headquarters—but they also found it convenient to name these places after some distinguishing feature of the particular locality. Such names were used as Chijol (the name of probably the most valuable wood in that country), Zapotal (the name of a grove of Chicle-Zapote trees from the juice of which chicle, the chewing gum of commerce, is made), Encinal (a place where there is a grove of oak trees), Palma Real (where the royal palm grows), and most interesting to the prospector, the words "El Chapopote," "El Chapopotal," "Chapopotilla," "Cerro de la Pez," and "Ojo de Brea," all words meaning tar or pitch. These were names given to places in the vicinity of which oil exudes existed. A glance at a map of this coastal region shows that places bearing names of this character

are found from the mouth of the Rio Grande on the north to and beyond the Guatemalan boundary on the south.

The Cerro de la Pez, or hill of tar, on the Hacienda del Tulillo, where we made our first land purchase and our first oil development, was merely by chance the first of these places we visited. The other places we later found, some of which we acquired,

SEEPAGE AT CHAPOPOTE HILL, MORALILLO.

many of which we made no attempt to acquire, might just as well have been the scene of our first exploitation as the one we selected.

Our application for a "new industry" concession attracted the attention of the government authorities and others in the city of Mexico, to the fact that another effort was about to be made to develop oil in the Republic. Attempts had been made before and abandoned for want of success.

Early Efforts at Oil Development—Forty-five years ago (1876), a Boston ship captain, having purchased at Tuxpam a quantity of "chapopote," or tar, for use on board ship, brought some of it with him to Boston, where it attracted the attention of his associates. A company was formed and he returned to Tuxpam, acquired a lease on Chapopote Nuñez and Cerro Viejo,

ONE OF THE EARLY WELLS DRILLED NEAR CHAPOPOTE NUÑEZ.

installed some of the machinery of those days (now obsolete) and managed to drill two or three wells to a depth of 500 or 600 feet. These wells yielded oil in small quantities. He built a little refinery on an island in the Tuxpam River, bringing the oil to the refinery at great expense, and treated it, producing kerosene, which he marketed in small quantities to the natives

in that region. His associates in the business refused to furnish the funds for further exploitation. The old captain became discouraged and committed suicide. His bones lie buried at Tuxpam.

Later, a man named Burke, of London, attracted the attention of the late Cecil Rhodes to the oil possibilities of the country south of the Tuxpam River. They formed a syndicate, called the London Oil Trust, in which Rhodes became a participant. After expending about £90,000 in a futile manner, they abandoned their direct efforts, and sublet their holdings to a company called the Mexican Oil Corporation, which also expended £70,000 in an unsuccessful effort to develop the property profitably.

The lands which these people operated were acquired for them originally by a very reputable citizen of Mexico, Sr. don José Maria Ortiz. An unfavorable report, made by the late Sir Boverton Redwood, on the prospectivity of these lands, was given us as the reason for the abandonment of exploration by the British companies.

Because of these unsuccessful efforts continued over a period of years, our plan was looked upon with little faith by most of the authorities in Mexico City. It was regarded as merely a Yankee scheme for selling oil stock in a plausible but unstable enterprise. Our undertaking to develop oil in reality received no encouragement except from the President of the Republic, Porfirio Diaz, and the Minister of Fomento, the late Blas Escontria. From both of these honorable men we received assurances of friendship and encouragement that alone gave us the heart to proceed with this enterprise.

The Minister of Hacienda, José Ives Limantour, requested the Geological Institute to nominate two geologists to make a report on the oil prospectivity of the Huasteca region, and especially of our Cerro de la Pez. The report of one of these men, Prof. Virreyez, who has since become very optimistic about Mexico's oil resources, was unfavorable. The report of the other, Prof. Ezequiel Ordoñez, was favorable, in fact, quite optimistic. The

latter was discredited by the Geological Institute because his report was so favorable.

Differences in Opinions—It seems, therefore, that in the first professional diagnosis of the oil prospects of the Huasteca region, and especially of our selected portion of it, the eminent doctors disagreed. Nevertheless, we obtained our concession and went ahead with our development, under a cloud of disapproval in Mexico City, which included everyone familiar with it, except

HEADQUARTERS BUILDING ON HILL AT EBANO.

the President, the Minister of Fomento, our attorney, and Prof. Ordoñez.

Our immediate and continued success only embittered the President of the Geological Institute and those who believe in the adverse report of his favorite geologist. That bitterness was shown toward Prof. Ordoñez, who quit the Institute because of it, and became a consulting engineer and geologist for various mining companies.

Four years after the reports were made, there was held in Mexico City a meeting of the International Geological Congress. I extended to them an invitation to visit Ebano. We had the pleasure of entertaining seventy-five members of the congress in our headquarters building on the hill at Ebano, whence we

took them to visit our various wells on a railroad, the building of which had been justified by the development which we had made.

A short time before the congress visited our camp the President of the Geological Institute in Mexico City exhibited a small vial of heavy tar to Prof. Ordoñez, saying to him in a sarcastic manner, "That is the whole of the production of Ebano." We were at that time producing over a half million barrels a year of petroleum, and had a small refinery in which we made asphaltum with which we had paved many miles of streets in the City of Mexico, all without the seeming knowledge of those who should be best informed about Mexico's mining industries.

Then, as now, the opinions of the long range experts seemed to be accepted by the public in general, and those of the practical, close range investigators were discredited. The experts of forty-five years ago caused the withdrawal of support from our Yankee sea captain, whose bitter disappointment led to his suicide. Sir Boverton Redwood (whom I had the pleasure of meeting in London shortly before his death, at a dinner given to Mr. Bedford), desirous of being conservative, I presume, and not realizing the opportunities afforded to him and his employers, basing his opinion upon investigations made by young geologists whom he had sent to examine the country, made an adverse report. He thus lost to his associates and his country the credit and the gain which would have been theirs had he visited the country himself and read aright the evidences which nature so bountifully furnished of the petroleum wealth of this region.

Further Acquisitions—In 1906, stimulated by our successes, we determined to go further afield and acquire new properties. This effort was due largely to a circumstance which arose out of the desire of my old partner, George J. Owens, who ten years previously had drilled for me in Peru.

Mr. Owens made investigations of lands and owners as far south as the Tuxpam River. A property situated in what is

now known as the Casiano basin, and which Mr. Canfield and I made fruitless efforts to acquire six years before, he found had been acquired by Count Julvecourt, after a previous Rodriguez option had expired. Julvecourt had transferred his rights to the Barber Asphalt Company. Julvecourt had also acquired the now well known properties called Cerro Azul, Juan Felipe and Gil de Solis. Owens learned that the Cerro Viejo and Chapopote properties were still held by the London Oil Trust. He immediately sent word to me at Los Angeles to come down and examine these properties. My associate, Mr. Canfield, having been subjected to an operation for appendicitis, was unable to go, so I induced my very good friend, Dr. Norman Bridge, Mrs. Doheny and others to come with me. We went to Ebano, got Mr. Wylie, general manager of our properties at that place, and together with Mr. Owens we examined these various prospects. Needless to say, we became much more enthusiastic than we were at the time of our first visit to the Huasteca, the inspiration coming not only from our prospecting experience in California, but also because of our success at Ebano. The lighter character of the exudes we also noted with much satisfaction. (Ebano 12° Baumé, Casiano 21°.)

The rain fell nearly every day that we were out on this trip. A small part of our journey from Tampico to the mouth of the Carbajal River was made by water, the remainder we made on horseback, through repeated showers of rain, which kept us wet from morning till night.

After we had reached the most distant place to which Mr. Owens guided us, we made up our minds that we wanted that property, wanted it badly, and wanted it right away. Mr. Barber, the head of the Barber Asphalt Company, was in New York; the office of the London Oil Trust was in England. After two months of negotiations and travel we became the owners of the subsoil rights of these properties, and of the surface as well as the subsoil rights of some of them.

The Casiano Development—Then began another period of development. The next most promising of our properties was Casiano, distant from Tampico sixty-five miles.

MR. HERBERT G. WYLIE, VICE-PRESIDENT AND GENERAL MANAGER.

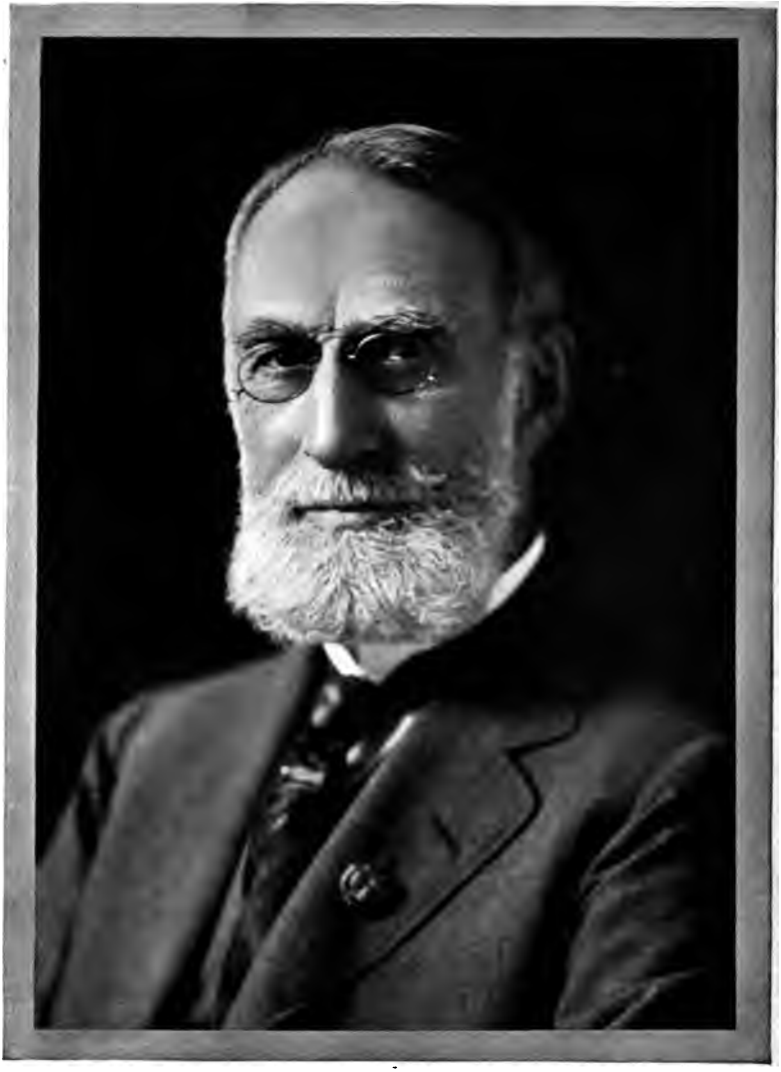
As we knew when we first saw Ebano that we were going to develop oil there in commercial quantities, so now we had faith in the productivity of this new district. We ordered sixty-five miles of eight-inch pipeline to build to this distant point where no oil had ever been developed, and eight large oil pumps and the boilers for the pump stations of the future. We ordered pipelines and pump stations, the tanks to accommodate the oil at the pump stations, the terminal storage, the derricks, drilling machinery and oil well supplies; at the same time we bought a right-of-way from Casiano to Tampico, except for a short distance. We constructed the pipeline in record time. We put in the pump stations complete with pumps and boilers and the necessary receiving tanks. Meanwhile we were drilling the wells for the oil to put through the pipeline.

Our calculations on making the pipeline pay were based on a minimum production of 3,000 barrels per day which we were confident we could realize.

One of our neighbors who owned a piece of land over which the pipeline route extended for a distance of twelve kilometers refused to sell us a right-of-way or to permit us to lay the line, so the line was laid from Tampico south to his place and from his place south to Casiano.

Our first well came in with a production which increased gradually at the end of ten days to 15,000 barrels per day. It filled all of our storage tanks. We closed the well to await the completion of the pipeline.

In our second well we found a much thinner stratum of hard rock over the oil deposit than in the first one, and consequently it came in as a surprise before the casing was lodged so as to make it possible to shut the well in. This well flowed at the rate of 60,000 or 70,000 barrels daily. When the valve was closed, it lifted the pipe and escaped outside of the casing, making an oil spring (300 feet away from the derrick), which flowed 3,000 barrels a day. By opening the valve, so that the pressure was reduced to 285 pounds, it was found that the well yielded about 23,000 barrels per day, and wasted no oil outside the casing.



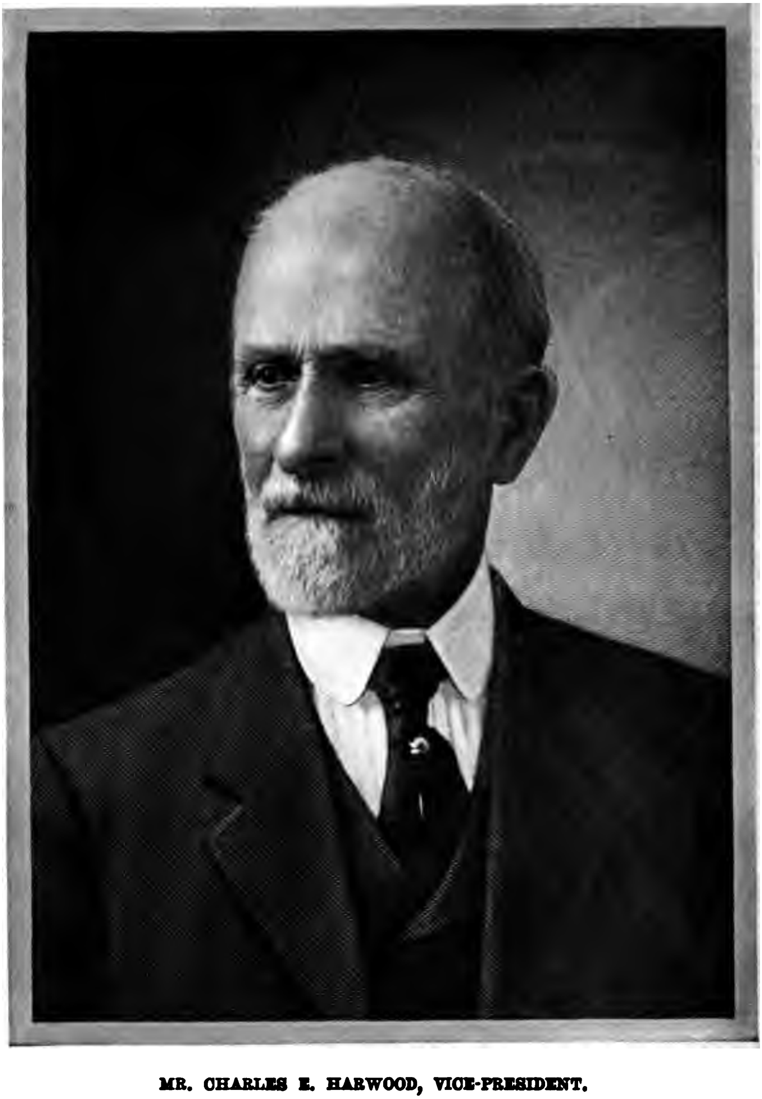
DR. NORMAN BRIDGE, VICE-PRESIDENT.

We obtained an order from the President of Mexico giving us the right to construct our pipeline across the forbidden land, upon our agreeing to pay such damages as an arbitrator might assess against us in favor of the owner. This section of pipeline, 7½ miles long, was built with a rush. The production of the well was turned into the line, under a pressure of 285 pounds, on the twentieth day of September, 1910. This pressure and production the well maintained until November, 1919, when it began to show signs of exhaustion, after yielding 85,000,000 barrels of oil.

Personnel of Organization—Our organization then consisted mainly of Mr. Canfield (since deceased), our first vice-president; of Mr. Charles E. Harwood, vice-president, now ninety-one years of age, whose great faith in our enterprise and its promoters never flagged (he made many journeys with me to Mexico in the early years of our development); of Mr. Herbert G. Wylie, our general manager, to whose untiring efforts, good judgment, vast knowledge and ability to overcome the unforeseen and seemingly impossible difficulties of engineering, and of working untried men whose language he did not then understand, a large part of our success is attributable; of Dr. Norman Bridge, vice-president, whose beaming intelligence, faith in his associates, cheerful and equable disposition, made him an invaluable companion and business associate; and of the humble writer of this narrative.

Without the co-operation and co-ordination of the abilities of these men there would have been lacking something which was vitally necessary to the continuation of our efforts through periods of discouragement which taxed the credulity of those not so well informed and put a responsibility upon the heads of the organization that they would have been loath to assume without the moral, mental and physical support of the other members of the outfit.

The desire to justify the confidence of our stockholders caused us to pay in dividends the net earnings of the Company. The need of investing large sums to develop our new areas necessi-



MR. CHARLES E. HARWOOD, VICE-PRESIDENT.

tated our turning to the banks, to get the money for these undertakings, on the credit which our enterprise inspired. In our home city of Los Angeles we failed to get the support which we sought. All of the earlier borrowings of the Company were made from two of the principal stockholders, Mr. Canfield and myself, who advanced a large part of the $3,000,000 which we invested at Ebano before our income began.

We were more fortunate when we attempted to raise money to build the pipeline from Tampico to Casiano. Being in a position to subscribe a large part of the money ourselves, the management secured its money requirements by what might be called inside financing. The development of this enormous well, which could not be shut in, made it necessary, however, to build millions of barrels of steel and cement storage to accommodate the flow of the well, until such time as a sufficient market could be found. One hundred and five 55,000-barrel storage tanks were erected in record time, also a 750,000-barrel reservoir.

Markets for Products—The markets were slow to absorb our product, although our first large customer, the Standard Oil Company, took from us 2,000,000 barrels a year for a period of five years, paying for a large part of it in advance, much to our relief. We found it necessary to build up a market. This we did with success in the New England States and other North Atlantic ports where the sales grew from nothing to its present measure of over 20,000,000 barrels per annum.

Ships were necessary to deliver this oil. The purchase of ships required money. We therefore undertook to raise the money on a mortgage of our property. The plan failed because of a pessimistic opinion of our oil property given to the people to whom we were trying to sell our bonds. In 1911 we came to know a young banker, the late George G. Henry. He listened to our enthusiastic description of the possibilities of our enterprise, believed in it, and induced his partners, Wm. Salomon & Company, to purchase $5,000,000 of our securities.

In order to place these bonds, however, a report by a reputable geologist and engineer was necessary, and one was selected for

the purpose, Mr. Ralph Arnold. He and his associate visited our properties at the request of the bankers in June, 1911, and spent two months there.

Yields of Important Properties—The Ebano district he valued at $1,200,000.

It had already produced over 10,000,000 barrels of oil, and for the last ten years has been producing at the rate of 5,000 barrels per day. No wells have been drilled there in ten years. Since this report it has yielded more than 18,000,000 barrels. Its total yield is nearly 30,000,000 barrels.

To the Casiano property he gave a valuation of $2,000,000.

That property has yielded over 80,000,000 barrels of oil since. Our Cerro Azul property he appraised at $1,056,000. We did not develop this property until five years after his visit, but during the last five years we have taken 70,000,000 barrels of oil out of it, and are at the present moment shipping over 200,000 barrels per day from that basin.

His total valuation on all of our properties was $9,438,000.

We determined to try and get our banking friends themselves to visit the property, believing it was only by actually seeing it that they could gain the confidence which we were quite sure the report of the geologist had failed to inspire. In the fall of 1911 they came.

The party consisted of twelve or fourteen well-known bankers of New York City, Philadelphia, Baltimore, Pittsburgh and Cleveland, with expert geologists representing some of the banks, the most eminent of whom was Dr. I. C. White, former State geologist of West Virginia, representing the banking house of Wm. Salomon & Company.

Dr. White's valuation on the Ebano district was $2,000,000, on the Casiano district $10,674,000, a total of $12,674,000, as compared to a total of $3,200,000 made by the first geologist. His valuation of the oil properties other than Ebano and Casiano was $50,000,000, making a grand total of $62,674,000, as compared with $9,438,000, the valuation of our ultra-conservative friend.

DR. I. C. WHITE, GEOLOGIST.

The visit of our bankers accompanied by the various geologists and by Dr. White, was justified by the difference in these reports. Here again the doctors disagreed, but the patient got well; that is, got his loan of money, which was justified by the optimistic appraisal.

The region visited by these two geologists in 1911 has since been developed to a considerable extent. Probably about one-third of its production has been exhausted. The remaining two-thirds have been proven to be oil territory. When this region is exhausted, the other great areas that have been marked by the Almighty as containing oil will still remain, developed and undeveloped, to add their quota, mounting into billions of barrels.

Looking Ahead--Up to the present the oil exudes found in numerous places along the Mexican coast have been the only guide for the development of oil. Such a guide has been successful, and it will continue to be so until the last of the petroliferous areas showing oil exudes is developed and exhausted. In this line of thought we must distinguish between the exude which denotes the existence of underground oil pools and those indications, such as impregnated surface rocks to be seen along the foothills of the Sierra Madre mountains, which indicate merely the dissipation of the oil theretofore existing.

The close examination of the ancient maps and the exploration of the surface of this gulf coastal plain show that of the total area a very small percentage is marked with oil seepages. The total amount of such areas being small, the oil pools which they indicate will be exhausted long before the discovery of the large number of oil pools which exist under the neighboring lands which have no exudes, but which may be directly connected with the places where exudes exist.

Quoting the best posted and most reliable of the Mexican geologists: "If the oil pools of the Mexican Coastal Plain exist only where oil seepages exist, then the life of oil production in Mexico is comparatively short, and could be estimated at from one to possibly two more decades, with a continuously declining production beginning within the next few years."

SEÑOR ORDOÑEZ, GEOLOGIST.

It is a fact that the existence of an oil exude in this region invariably means the close proximity of a volcanic plug or dyke, whether visible or hidden underground. Practically all of these exudes are located near such basaltic plugs or dykes, and a great many of them are found at the contact between the volcanic and sedimentary rocks, as in the case of Cerro de la Pez, Moralillo, El Chapopote, Cerro Azul, Las Borrachas, Gil de

SEEPAGE AT TIERRA BLANCA.

Solis and Chapopotal. In these cases the sedimentary rocks are always of shale, sometimes, however, overlaid by marls and sandstones. The necessity for the co-existence of these basaltic cores and oil exudes along this coastal plain is resultant from the following facts:

First—Very thick bedding of impervious shales which cover and hermetically seal the underground oil pools, thus preventing their waste.

Second—The absence of important faults in the shales.

Geological Features—The oil which makes its way to the surface generally follows the contact between the basaltic rocks and the sedimentaries, along which contact it finds a place of least resistance. Occasionally these exudes follow up through crevices produced by old volcanic explosions above a mass of underground basalt which has not reached the surface. In any case, the oil

TYPICAL BASALTIC PLUG, CERRO VIEJO.

coming up to the surface of the ground does so against great resistance. The development in many places, notably at Ebano, demonstrates that the volcanic phenomena which resulted in these basaltic plugs and dykes has contributed in no uncertain measure to the existence of the areas of dislocation and cavities which afterwards became filled with oil through a very slow process of accumulation. The larger these basaltic dykes and plugs and the more frequently they are encountered, the larger will be the

number and the size of the oil pools in their proximity. It is not meant to contend that where there are no basaltic hills or ridges, there no oil will be found, because it is admitted that the volcanic phenomena are not indispensable to the formation of oil pools in Mexico. And, furthermore, the number of underground masses of volcanic rock which make no appearance on the surface, except possibly by a fracture, is very great. This has been demonstrated by the bodies of volcanic sand as well as rock drilled into, at Chijol and in other places where no exposures of volcanic rock appear on the surface. It is altogether likely that where there is a total absence of basaltic rocks in a given area there will be oil pools of more moderate size than those heretofore developed. It is also quite likely that in these numerous hidden oil pools rests the more remote future of the oil production in Mexico.

There are two questions of vital interest in this connection:

First—Do the oil seepages sparsely scattered over an immense area indicate with certainty the existence of pools of oil in the vicinity beneath? The experiences of the last twenty years give the answer to this question decidedly in the affirmative.

Second—Are there substantial pools of oil in places far away from the vicinity of these exudes and also far away from any form of volcanic action or volcanic rock masses? To this we venture the reply "Yes."

Having answered both these questions in the affirmative, a further question might be asked with relation to each of them:

How to look for and discover the much-desired oil pools?

Where oil exudes indicate the existence of oil pools beneath, a careful study should be made of their nature and occurrences, so as to determine, if possible, whether the oil exudes are part of a series of exudes which indicate a line of fracture or dislocation extending in any particular direction. Often careful search will reveal that the exudes continue along a definite line, and that drillings made at *right angles* with the extension of this line will determine where the pool is located and its width, after which drillings *along* the line of exudes will reveal

the extent of the pool or pools. Sometimes a study of the stratigraphy of the rocks which appear on the surface in the vicinity will indicate the position with relation to the exudes that the uplifted, anticlinal or domal structure bears.

It is well known that in Mexico, as in California and other places, the topography of the surface is not a safe guide as to the faulting of the rocks beneath. The bed of an arroyo or a valley is often located along the axis of an anticlinal, the rocks

SHEET OF STICKY OIL FROM SEEPAGE, JUAN FELIPE.

dipping both ways, and the valley becoming the natural site for wells to be located to penetrate the top of the fold and get the gas pressure and oil production, if there be any, underneath. It must be borne in mind in making these investigations that great care and good judgment must necessarily be supplemented by good luck in order that results may be frequently obtained. In our drilling experience at Ebano we endeavored to follow the reasoning which I have attempted to set forth, and we have found that there are oil bodies existing under at least three different conditions in this section. These may be described as being those oil pools found at the place of contact between the

sedimentary and the volcanic rocks, penetrated by wells drilled close to the base of the volcanic hills which reach to the underground reservoirs somewhere along the area of contact. Other pools were found by following lines of exudes which appear on the surface, extending from the base of a volcanic plug in many directions, some of which lines usually extend to greater distances and show more continuity and life in the exudes than

ACTIVE OIL SEEPAGE; NUMEROUS BUBBLES.

the other lines. Along these lines radiating out from the plugs we have drilled wells with almost invariable success. As the fracture of a pane of glass decreases in its force from where a rock or bullet penetrates the glass to the end of the fractures, where the force spent by the missile is exhausted, so these volcanic plugs sometimes fracture the sedimentary rocks in many directions, and where they are located in the vicinity of other volcanic plugs, a fracture often extends from one plug to another, indicating a line of greatest force or disturbance, and possibly

the existence of a hidden dyke connecting the two plugs, but not itself appearing on the surface as is the case between Cerro de la Pez and Cerro la Dicha at Ebano, and Pelon and Cerro de Las Borrachas on our Juan Felipe property, except in the latter case the volcanic dyke does appear at the surface or give evidence of its existence by detached masses of basaltic rock being found along the line between the two hills, which is more than three miles.

In many cases we have drilled on these lines of fracture,

SEEPAGE AT CERRO PELON.

locating the derrick directly on the line, and having drilled to a depth beyond which we did not expect results, we have moved the derrick in one case only eight feet, in another twenty-two feet, and developed a pool of oil with the second hole, thus justifying the second drilling. Sometimes it was necessary to drill the third hole not very far distant, but on the opposite side of the fracture from the second—the first being located on the line of fracture.

Small Seepage May Indicate Substantial Pool— Thus we have demonstrated that a very small seepage may be the location of a substantial pool which is not directly under the seepage,

but is to one side of it, and this can only be determined by drilling a second well, which, if unsuccessful, must be followed by a third in order to discover whether there is or is not a pool in the vicinity of the exude. This very close fine-tooth combing of the possible oil regions of Mexico has only been done so far to a very slight extent.

SEEPAGE AT CERRO LAS BORRACHAS, JUAN FELIPE.

It must be kept in mind that the sedimentary formations which appear at the surface and which the wells penetrate to a depth of 2,000 feet, more or less, were distributed by the waves of some primitive ocean over a surface of rocks already faulted, broken, and uptilted, and that after the deposit of these sedimentaries, they were themselves penetrated and faulted and disturbed by the volcanic plugs and dykes which were forced up through the faultings of the underlying limestones, and up and to the surface through the hundreds of feet of sedimentary rocks deposited on

the limestones. The evidence of these subsequent actions to the uptilting and folding of the Tamasopo limestones is every-

ASPHALT AND ACTIVE SEEPAGE, IN SOUTHERN FIELDS.

where discernible throughout this region, and as the sedimentary rocks were and are impermeable, the basaltic masses forced up through the sedimentaries, created a passage for the

oil to accumulate on the surface along the contact and through the dislocations made by the basaltic plugs. Inasmuch as the basaltic plugs forced their way upward through the faults and breaks of the Tamasopo limestones, in most instances the anticlinal foldings or the domal structure of the sedimentaries for which the volcanic plugs, both visible and invisible, are responsible, occupy a position above the corresponding foldings in the Tamasopo limestones which existed long before the existence of the sedimentary rocks. It is in this way that the domes and anticlines of the limestones and shales of the earlier period where the oils and gases would naturally collect, are almost invariably beneath the disturbances, domal and anticlinal, in the later sedimentaries, which latter become the most likely places for the drilling of wells to reach the subterranean pools. It is not reasonable to suppose that all of the anticlinal folds of the earlier Tamasopo limestones were the location of subterranean influences which forced basaltic masses up through them to the surface. In these cases there would be little, if any, evidence on the surface, of the existence of the anticlinal fold beneath, and of the subterranean oil pools which would naturally collect under such conditions. These places then become the sites of the hidden pools which have no basaltic plug or exude on the surface to indicate their locality, and which must be found, if at all, only by the careful and scientific investigation of the rock conditions, both close and remote, drawing conclusions from the developments of other localities and possibly depending upon the determination of the extension of some line of exudes in some distant field for the information which may lead to their discovery.

CHAPTER III

DEVELOPED AND UNDEVELOPED LANDS

MEXICO, which at the beginning of this century was unknown as a land of oil, is now the second largest producer of petroleum in the world. Many of the valleys which today are scenes of restless activities were then scantily populated, and over them cattle roamed, or were mired in the exudes of oil to the dismay of their owners. Much of the uncleared land was covered with a jungle growth so dense as to shut out the sun, and formed a serious obstacle to those who first ventured within its pathless depths in search of oil. The discovery of oil in Mexico is due to the men who formed the Mexican Petroleum Company of California.

Investigation was begun on lands in proximity to the Mexican Central Railway, which had been extended to Tampico in 1890, and which would offer a ready market if the territory proved to be oil-producing. Near kilometer post 613, which was afterwards named Ebano, extensive oil exudes were discovered. Several contiguous tracts of lands in this neighborhood aggregating 450,000 acres were purchased in 1900, and the Mexican Petroleum Company of California formed for the purpose of developing these lands was incorporated on December 20, 1900.

This Company has the honor of being the first producing oil company in Mexico, and not until several years after the first drilling at Ebano did any other company find oil in commercial quantities in the Republic. It is true that the Aztecs and the Spanish conquerors collected oil from the seepages and used it as did the Incas of Peru and the early inhabitants of Rumania and Mesopotamia. Spasmodic efforts were also made during

the closing years of the nineteenth century to reach the oil, and many pathetic reminders of these failures are found in the jungle today; but none of them had any success until the Mexican Petroleum Company began operations twenty-one years ago.

Ebano Fields—Immediately after the purchase of the Ebano property, preparations for development were begun, and in February, 1901, a railroad spur was built to facilitate the delivery of material to the places selected for drilling and the building of a camp.

ENGINE ON COMPANY'S RAILWAY AT EBANO.

The site chosen is strikingly picturesque; the buildings cover the summit and flanks of a cone-shaped hill known as Cerro la Dicha, and there is probably no better equipped camp today in Mexico. The thoroughness with which the General Manager, Mr. Herbert G. Wylie, planned this camp so that it might be efficient, sanitary and have the features of a home, may be judged by an enumeration of a few of the buildings. There was installed immediately an ice and cold storage plant to provide pure water and proper refrigeration for meats; in a short time there was built, in addition to the necessary offices,

a boiler and blacksmith's shop, and a large supply warehouse. Good houses were constructed of brick or wood for all employees, and a large recreation room, which is without any rival in the Republic of Mexico. Water was brought through a six-inch line from the Tamesi River, which is about fifteen kilometers from the camp at Ebano. Under the direction of a medical

DUGOUT—ON TAMESI RIVER.

doctor appointed by the Company, a hospital was built and equipped.

For several years the annual reports were monotonous in regard to expenditure and little income. Each year saw an increase in the production of oil, but with depressing sameness the management had to report there was no sale for it.

The gusher Pez No. 1, yielding 1,500 barrels a day, which

was drilled in on April 6, 1904, caused the greatest satisfaction to the Company, but it only made the question of sales more acute. Gusher conditions called for more outlay as the oil must be stored, and ultimately, around Ebano, tanks and reservoirs with a capacity of 678,986 barrels, were built. It may sound

ONE OF THE FIRST WELLS AT EBANO.

almost incredible today to report that from 1901 to 1905 no substantial market for fuel oil was available. Negotiations with the Mexican Central Railway were concluded on May 10, 1905, and a contract was signed for the supply of 6,000 barrels daily, for a period of 15 years. This was the first contract made by the Mexican Petroleum Company. It is small compared with con-

tracts today which total 30,000,000 barrels, but at a moment when it seemed impossible, without great expenditure, to sell fuel oil, it was a propitious beginning.

Within a few years the Company produced and sold over 15,000,000 barrels of oil. Deliveries were made under the terms of the contract until its termination in 1920, with the exception

SEEPAGE AT CERRO LAS BORRACHAS, JUAN FELIPE.

of inevitable interruptions caused by the unsettled political conditions in Mexico which arose in 1910.

When the Huasteca Field was developed in 1910, drilling at Ebano was halted, but the wells are producing an average of 150,000 barrels monthly.

Huasteca Fields—The success of a company depends as much on the vision of its directors as upon the development of acquired territory, and exploration went hand in hand with production.

Ebano had been proven to have great possibilities, and additional oil lands were sought for, south of the Panuco River.

To one who visits the southern oil fields of Mexico by means of modern roads crowded with motor traction from Fords to ten-ton caterpillars, and by railways and gasoline launches, it is difficult to imagine what the territory was like when the value

SEEPAGE NEAR CAMPECHANA.

of these lands was first discovered. The country was one vast, almost impenetrable jungle. The simplest food was often difficult to procure; and after a weary day beneath the rays of a scorching sun, or laboriously cutting a way through the thick growth, one's night was tortured by insects from which no improvised shelter furnished any protection. To make a pathway through territory of this kind, untouched for centuries, and with no knowledge of what lay ahead, is the acid test of endurance and confidence.

It had been relatively easy to prospect around Ebano, as the railroad had opened up the country, but in the southern fields there was neither rail nor road, and only rarely trails. Lake Tamiahua, a large sheet of water joined by a canal with the Panuco River, connected the known district around Tampico with the unknown Huasteca region. Humidity and heat in the tropics, annoying enough in themselves, promote a growth pleasingly luxuriant to the spectator, but so tangled and bewildering to the pioneer as to call up every reserve of fortitude and endurance. In these fields no axe had rung through the woods for generations, and the jungle formed by centuries of growth and decay was dark and menacing. The early explorers found not only the jungle, they were also obliged to wade through swamps and marshes, and ford rivers with their own peculiar dangers.

Lands were acquired during the years 1905 and 1906, in the Huasteca region, and a company formed on February 12, 1907, called the Huasteca Petroleum Company. A new company—the Mexican Petroleum Company, Ltd., of Delaware—was incorporated on February 16, 1907, which today owns 1,400,000 acres of land in Mexico, and over 4,000,000 barrels of storage at distributing stations, in North and South America.

The market for the oil at Ebano was for many years restricted, and opportunities for its sale outside Mexico did not present themselves until nearly ten years after the original company was organized. During 1909 the outlook seemed to justify development on a larger scale, and preparation was made for drilling in the Casiano basin. The experience of gusher conditions at Ebano, and the very promising surface indications in the Huasteca territory, led the management to make provision for a flow of oil simultaneously with the drilling.

The drilling rigs were erected on two sites named Casiano 6 and Casiano 7. Both wells came in during 1910; Casiano 6 with a capacity sufficient to fill two 55,000-barrel tanks in a short time, and Casiano 7, which proved to be the larger of the two. During the drilling of these two wells, the building of the pipe line and pumping stations and constructing the roadway

was pushed forward with all possible speed. Hundreds of workers were employed in cutting down trees and clearing away the jungle growth. Barges were built for crossing three rivers —La Laja, Cucharas and Carvajal. Water was taken from the Tancochin and Cucharas, and pumped to the stations which were erected at Garrapatas, Horconcitos, La Laja, San Geronimo and Casiano. Two water supply stations were built, one at Esper-

CROSSING THE RIVER CUCHARAS BY BARGE.

anza, several miles from the mouth of the Cucharas River, and the other on the Tancochin, near Casiano; a third has been completed in 1922 at Juan Felipe.

Casiano No. 7 was drilled in on the morning of September 11, 1910, and flowed without interruption at the rate of between twenty and twenty-five thousand barrels a day until November, 1919.

The largest well in the world—Cerro Azul No. 4—was completed by the Company on February 10, 1916, and closed in on

February 19th. The features of the bringing in of this well are so remarkable, that a separate account is given in the chapter on "Three Famous Gushers." The requirements of the Company were met by Casiano No. 7 and Cerro Azul No. 4 until recently. Several new wells have been drilled since February, 1921. A complete list of the producing wells in the Southern Fields, with the date of completion and estimated production is as follows:

Name of Well	*Completed*	*Potential Production Barrels*
Cerro Azul No. 4	Feb. 19, 1916	260,858
Cerro Azul No. 3	Apr. 23, 1921	30,000
Cerro Azul No. 7	May 1, 1921	75,000
Tierra Blanca No. 1	May 21, 1921	75,000
Cerro Azul No. 9	Aug. 30, 1921	100,000
Cerro Azul No. 8	Nov. 8, 1921	100,000
Cerro Azul No. 11	Nov. 11, 1921	100,000
Cerro Viejo No. 3	Nov. 20, 1921	40,000
Cerro Azul No. 12	Dec. 29, 1921	25,000
Cerro Azul No. 10	Dec. 30, 1921	25,000
Cerro Azul No. 15	Feb. 7, 1922	75,000
Cerro Azul No. 16	Feb. 18, 1922	25,000
Cerro Azul No. 14	Feb. 18, 1922	20,000

No period in the history of the Company in Mexico has shown so much activity as at the moment of going to press. Pipe lines, pumps and refinery are being utilized to the limit of their capacity. The monthly output from October 1, 1921, until March 31, 1922, was as follows:

October,	1921	3,445,854.23	Barrels
November,	"	5,828,351.08	"
December,	"	7,529,015.50	"
January,	1922	6,699,089.79	"
February,	"	6,549,988.42	"
March,	"	6,689,846.84	"
Total		36,742,145.86	barrels

Terminal Near Tampico—The River Panuco and its chief city Tampico, six miles from the bar, was a few years ago unknown outside of Mexico, save to the officers and crews of occasional vessels. Today, numerous tanks, offices and workshops have been built on the banks of the river from its mouth to Tamos beyond Tampico. Many oil companies have their terminals here, and the oil from the southern fields flows through pipe lines to the wharves, whence it is shipped to both hemispheres. The shipping in the river, owing to the incoming and outgoing tankers, has raised the port from a position of unimportance to one of the principal traffic centers in the western world.

Arriving at Tampico a few years ago, baggage was carried by porters, and only rarely could one have a horse-drawn vehicle. Automobiles did not exist. Today, numerous cars occupy the stands in the city or dart through the crowded streets. As recently as 1916 it took an indefinite period to reach the Southern Fields. The road was completed, but automobiles had not been delivered. Owing to the treacherous nature of Lake Tamiahua, which is sometimes suddenly swept by storms, a day or even two might be spent in travelling from Terminal to San Geronimo. These 52 miles can now be covered in three hours over a well-paved highway, and the three rivers between these two points crossed by barges which carry the automobile.

The Huasteca Petroleum Company has the largest and best situated terminal on the river. It occupies a section of land 651 acres in extent, on the right bank of the river, about four miles from the Tampico bar. A large wharf, 1,500 feet long, has been constructed capable of accommodating simultaneously three of the Company's largest tankers. The land rises somewhat abruptly from the river's bank; and as the tanks are built on the higher portion of the land, the oil flows by gravity through 16-inch lines to the wharf. The hose pipes at the wharf are 8-inch, and three vessels of 10,000 tons can be loaded at the same time, each at the rate of 6,000 barrels per hour.

The Company has 58 automobiles and 50 trucks; in addition there are two fire trucks for emergencies, and 20 caterpillar

tractors which are employed to carry engines, boilers, lumber for the construction of rigs, and pipe line equipment. All roadways through the properties are crowded from dawn till sunset.

Communication between Terminal and Tampico is maintained by means of fifteen launches, and thirty-four barges, which ply at regular intervals. There are seven tugs to handle the barges and the fleet of thirty-one tankers.

CATERPILLER TRACTOR IN JUNGLE.

Near the waterfront and landing stage, are the general and marine offices, a laboratory for testing the oil before shipment, a carpenter, and a machine shop, electric light plant, foundry, boiler house, lumber shed, painter's shop, warehouses whence material is shipped to the various fields, a garage, a commissariat, an ice plant and a laundry. On the higher ground, behind these buildings, are large dining-rooms, offices of the accounting de-

partment and engineering staff, and the residences of the Terminal Superintendent, American, and many Mexican employees.

Scattered over a large area near the summit of the rising ground are 49 tanks and 1 reservoir, with a capacity for storing 3,414,000 barrels of oil. The first section of the refinery at Terminal was built in 1914 and consisted of 3 units capable of handling 30,000 barrels daily. An addition was made to the refinery in 1915 bringing its capacity up to 75,000 barrels. During 1921 a second plant was completed with 4 batteries of 6 heaters each which can treat 60,000 barrels daily. There is also a viscosity plant with 3 heaters which can, when necessary, add 5,000 barrels to the capacity of the refinery, making a grand total of 140,000 barrels daily.

Most of the fuel oil is stored at Tankville, which lies about 3 miles beyond Terminal. There are 58 tanks at Tankville of 55,000 barrels each, making a total of 3,190,000 barrels or a grand total of 6,604,000 barrels at Terminal and Tankville.

At Terminal and throughout the fields thousands of Mexicans are employed, some of whom are doing highly skilled work. Three school houses have been erected by the Company where the children receive daily instruction in elementary subjects, and recreation is provided for them as well as for the employees. The instructional value of the Company's business to many of the workers is incalculable, some of whom have acquired very valuable knowledge of the technical side of the business.

The health of all employees is carefully attended to by a staff of doctors and trained nurses; in addition to the doctor and hospital at Ebano already mentioned, there are seven doctors, four nurses, two fully equipped hospitals, and two emergency hospitals at points of greatest activity between the Panuco and Tuxpam rivers.

Twenty years ago the inhabitants of the oil districts of Mexico utilized the methods of transportation which had obtained for centuries. The boats on the rivers were merely dugouts, and on land they carried their produce or it was borne on the backs of mules or donkeys. There is no external feature which so

clearly marks the difference between the undeveloped and the most progressive nations as the difference between the methods of moving their goods. Progress to a great degree is determined by speed and ease of communication. The Mexicans have learned many modern methods of work during the twenty-one years of the Company's activities in Mexico. A new world has been

CHILDREN AT ONE OF THE COMPANY'S SCHOOLS.

opened to them, and their knowledge of the intricacies of machinery and time-saving appliances should be of immense service to them in the development of this country of great possibilities. Thousands of men who would have learned nothing beyond what is necessary for tilling a small plot of land, have assisted in the laying of pipe lines, the building of pumping stations, the installation of pumps, drilling for oil, and the numerous activities connected with the production of petroleum. They have thus gradually become acquainted with the working

and handling of one of the greatest and most important industries of the world. The faithfulness of the Mexican workers has been frequently emphasized by officials of the Company, and on occasions when political troubles necessitated the withdrawal of Americans, the Company was able to continue the shipment of oil chiefly owing to the loyalty of the Mexican employees.

PRIMITIVE TRANSPORTATION IN MEXICO.

Huasteca Pumping Stations—In the southern oil fields of Mexico, which begin north of Estero de Carvajal and extend beyond the Tuxpam River, the oil wells are gushers. The oil at the wells is controlled by valves which are opened sufficiently to allow the daily requirements to flow. The oil spouting from the ground carries with it gas, which must be separated, and this is done near the wells. When the gas is removed, the oil flows to the pumping station, a number of which have

been built between the wells and the wharf at Tampico. Between Terminal and Cerro Azul there are five stations, namely:

NATIVE MEXICAN AND CHILD.

Garrapatas, Horconcitos, La Laja, San Geronimo, and Casiano, with an average distance between them of 14 miles. The pumps at these stations are all of the Wilson-Snyder design and construction, two types being used—the Compound Duplex

and the Compound Corliss Duplex. Before installing these pumps, thorough investigations were made in order to secure the type best suited to the work in Mexico, and after years of trial they have proved to be eminently satisfactory. The sites for the stations were carefully selected and when the stations were built each pump house was equipped with one horizontal cross compound crank and fly wheel high duty pumping engine. Each pumping engine has a 28″ high pressure steam cylinder, a 54″ low pressure steam cylinder, and 6½″ plungers, all 36″ stroke. In each station there was also installed one horizontal compound duplex plunger pump, having a 25″ high pressure steam cylinder, a 42″ low pressure steam cylinder, and 9½″ plungers, all 36″ stroke.

Owing to the different speeds at which each machine was designed to operate, their capacities are the same, but the crank and fly wheel engine weighs twice as much as the duplex pump and uses half as much steam. The design was such that the unit or "knocked-down" weight of each machine was kept at a minimum for transportation, though each assembled unit resulted in each case in a rugged pump, amply strong to withstand the maximum pressure produced. This element of strength was so accurately calculated that the pumps, which have been in constant service since 1910, have never had a broken part, nor have the lines been shut down once through failure of the equipment.

Three units of water tube boilers were installed at each station, because of the economy of this type, ability to carry overload, and comparative ease of handling; and these boilers are equipped for burning oil, gas, or both. Horizontal cylindrical oil heaters were installed and these were so set that the oil, before entering the pumps, can pass through any one or all of the heaters, either in series or in parallel, or they can be bypassed altogether, and the unit installation permits of increasing the number indefinitely without interfering with the operation of the station. The heating method is exhaust steam, the water of condensation being automatically returned to the hot well and thence to the feed water heater. The excess exhaust steam, if

any, goes to the feed water heater, which is supplied from the hot well. In this way there is practically a closed system, using a minimum of water supply and allowing the introduction of the oil to the pump at the most efficient temperature, and of the water to the boilers at 200° Fahrenheit. At the same time practically all of the exhaust steam is used up.

The crank and fly wheel pumps were intended to be used for regular service and the duplex pumps as stand-bys or spares.

PUMP HOUSE AT LA LAJA.

Under these conditions one boiler at its most economical overload would supply sufficient steam for operating the crank and fly wheel pump at its full capacity. Two boilers similarly operated would run each duplex pump. In this way there would be one spare boiler and also either pump would give what was then the maximum capacity.

The pumps are protected by various governors of special design to safeguard them in any operating emergency. Should the line break, thus relieving the pumps of practically all load, the steam is automatically shut off and the pump stops. If a

gate valve in the line be closed and pressure beyond the margin of safety built up, the steam is shut off and the pump stops. Should the pumps be started before the suction line is open they will not "run away." They are amply protected for either over or under load. The boilers and boiler feed pumps are equipped with feed water regulators to maintain the proper levels and with governors for speed. This control has been so successful that when some years ago all the operating engineers were obliged to leave the country the stations were operated continuously for six weeks by native labor without breakage or shut-down.

The supply of oil and the demand for it increased so rapidly after 1910 that additional lines had to be installed and the stand-by pump was soon in regular service with the crank and fly wheel pump. Today each station contains 16 boilers and 6 pumps, with space for two more pumps in the same building, and provision for further extension. The original equipment has been duplicated throughout with each increase, and the operating methods are the same, thus thoroughly vindicating the original engineering and selection.

The first station south of Terminal is Garrapatas. There is storage at Garrapatas for 67,000 barrels of oil, and a wharf on the lake where material shipped from Terminal was landed for the building of the station before the roadway was completed. South of Garrapatas is Horconcitos, one of the most picturesque of the stations, which is also provided with a wharf on Lake Tamiahua. The storage at Horconcitos is similar to that of Garrapatas. Practically all transportation as far as San Geronimo is by road, which has been completed recently from the Panuco to the Tuxpam River. The roadway is also used for carrying the pipe lines.

About fourteen miles south of Horconcitos is La Laja, situated on a river of the same name, which flows into Lake Tamiahua. The storage at this station is 24,000 barrels. Between La Laja and San Geronimo two rivers are crossed by barges—the Cucharas and the Carvajal. The Cucharas River is one of the

most beautiful of the smaller rivers in Mexico, and on one of its numerous picturesque windings is built one of the Company's water stations, named Esperanza. South of the Carvajal River is San Geronimo, which has tanks with a total capacity of 67,000 barrels. Beyond this point the roadway diverges from the lake and traverses attractive country distinguished by conical-shaped hills and verdant valleys, where the

STATION AT GARRAPATAS.

land, tilled by the Mexicans, gives rich harvests with a minimum of toil.

San Geronimo is the terminus of the Company's railroad, which runs south to Chapopote Nuñez, fifty miles distant, supplying the camps of Casiano and Cerro Azul, and the various centres of work through what is now the busiest section of the oil fields. The railroad between San Geronimo and Kilometer 22 near Casiano was completed on January 4, 1913, and the extension to Cerro Azul on January 16, 1914. It is now being ex-

tended to Chapopote Nuñez. Around this railroad flourishing towns have grown up with amazing rapidity on what a few years ago was jungle land. This railroad has been of immense service to the Company in transporting material for construction work, and at the present time both railroad and highway are crowded

CUCHARAS RIVER AT ESPERANZA.

with traffic. In 1916 it required at least two days to visit the stations between Terminal and Cerro Azul. Today one can leave Tampico in the morning by automobile, visit each pumping station, and arrive at Tierra Blanca camp, near the Tuxpam river, one hundred miles distant, in the late afternoon. The storage at Casiano consists of six tanks with a total of 300,000 barrels, and Cerro Azul has storage for 97,000 barrels. A new pumping station has been erected at Tierra Blanca where there are three tanks of 55,000 barrels each.

The first thing which strikes the visitor to the stations is the coolness of the boiler rooms, and the scrupulous care that is taken to keep everything clean in and around the station. Some of these stations have a most beautiful setting, as they are surrounded with the prodigal growth and wealth of the jungle. Towering over all other growths are the royal palms, and carelessly nestling on the branches of the trees are rare and exquisite orchids. Birds of striking plumage and butterflies with wings of dazzling colors reveal the inimitable harmonies of nature, defying the brush of a Titian, or the pen of a Ruskin. Flowers and fruit trees have been added under the direction of the station superintendents, and the huge sheltering leaves of the banana, scarcely moving in the still air, grace the well-kept walks around the station.

After the rains come, the trees are clothed with leaves, which exhibit every variety of beauteous form and shade. Darker greens intermingle with the lighter shades of the air-plants, which hang festoon-wise from the branches. The growth of this tropical land furnishes an arrestive picture of the riotous abandon and disorder of Nature, till the spectator forgets that he is not within a land of dreams, and expects the gnomes and elves of fairyland. Nature left alone in the tropics produces a dense tangle of vegetation. Some of the trees are large and branch widely, so that when in full leaf they form a canopy overhead. Over all the trees runs a vast network of creeping plants and vines, which range from threadlike filaments to hawser-like arms of great strength, mounting serpent-wise amid the tree trunks or searching downwards in weird loops and threatening free-swinging ends. Parasitic plants, mosses and ferns settle wherever there is an available space on the limbs and trunks of the trees, many of which carry a greater mass of parasitic growth than they do of their own foliage. Life menaces life, and the trees which grow so easily are threatened by entwining parasites in a menacing ceaseless struggle, till in the end the tree becomes merely a supporting lifeless trunk.

A few minutes from a roadway, slashed out of an endless

thicket of perpetual twilight, and crowded with traffic comparable to the busiest roads in the United States or Europe, broods the silence of the tomb. A more vivid contrast than the pathway bustling with automobiles, tractors, trucks, mule wagons, and the riotous motionless growth and decay of the jungle to the depths of which the fierce rays of the tropical sun never

SECTION OF CERRO AZUL CAMP.

reach, can scarcely be imagined. Amid these scenes of silence and bustle have been built the stations, and the homes of those engaged at work in them. The company has many camps between San Geronimo and the Tuxpam river. One of the most active of these, and which has recently been rebuilt, is situated at Cerro Azul. The camp stands on a knoll at the base of the hill which has given the name to the locality, and is without any rival south of the Panuco. The chief aim in preparing the plans was to make the conditions under which the employees live, healthy and homelike. This camp situated in the heart of the

Mexican jungle has every modern convenience, and the large Club room is furnished with billiard tables, and many other forms of relaxation. All the stations and camps are connected by telephone with the head office in Tampico, and the superintendent, Mr. William Green, can get into touch with any section of the fields, and with all the stations, by day or night.

Pipe Lines in Southern Fields—The Company has in the

WATER STATION AT ESPERANZA.

Southern Fields of Mexico 531 miles of pipe line. Owing to the nature of the climate, it is not necessary to bury these lines deeply. They are placed at or near the surface, and in the event of a break can be quickly repaired. The pipe lines between the Panuco and the Tuxpam rivers are in charge of a superintendent, whose duty is their care and repair; a broken line not only means loss, it may mean interruption of the work at the refinery in Terminal, which is one of the most valuable assets of the property.

MR. WILLIAM GREEN, VICE PRESIDENT AND GENERAL SUPERINTENDENT OF HUASTECA PROPERTY.

The first of the pipe lines was built simultaneously with the drilling of Casiano No. 7, and was completed when the well came in, with the exception of a few kilometers which had been delayed owing to prolonged negotiations in regard to the purchase of the right-of-way. Before a well was completed at Cerro Azul, two 8-inch lines had been laid between Casiano and Cerro Azul, and two additional lines between Casiano and Terminal. These sufficed for the Company's requirements until 1921, when additional lines were laid, necessary for the increased production of that year. The main oil lines of the Company exclusive of auxiliary and branch lines are:

Terminal to Casiano: (About 66 miles)

Line No. 1— 8-inch pipe.....Completed in 1910
Line No. 2— 8-inch pipe.....Completed in 1911
Line No. 3— 8-inch pipe.....Completed in 1914
Line No. 4—10-inch pipe.....Completed in 1921
Line No. 5— 8-inch pipe (joining No. 4 at Kilometer 13).....Completed in 1921

Casiano to Cerro Azul: (About 16 miles)

Line No. 1— 8-inch pipe.....Completed in 1913
Line No. 2— 8-inch pipe.....Completed in 1915
Line No. 3— 8-inch pipe.....Completed in 1921
Line No. 4—10-inch pipe.....Completed in 1921

Cerro Azul to Tierra Blanca: (About 19 miles)

Line No. 1—10-inch pipe.....Completed in 1921
Line No. 2—10-inch pipe.....Completed in 1922

Storage Tanks and Reservoirs—Oil is stored in Mexico either in reservoirs or tanks. The Company has two large reservoirs capable of containing 1,075,000 barrels, and 157 tanks, together making a total of 8,356,000 barrels. The tanks are cylindrical in form and each one is surrounded with an earthen embankment, or "fire-wall," enclosing a space from one to one and one-half times the volume of the tank, so that in case of a tank bursting, or fire, the oil may be confined within the "fire-wall." The most common size of tank contains 55,000 barrels. The diameter of

these huge cylinders is 114 feet 6 inches and their height 30 feet. They are built in six graduated rings, the heavier being at the bottom.

In 1910 the Huasteca Petroleum Company built a 55,000-barrel tank every four and a half days. A gusher seems to inspire the workers with some of its own restless energy, and phenomenal

GENERAL VIEW FROM REFINERY NO. 1, TAMPICO.

achievements in building storage tanks, laying pipe lines and erecting the refinery have been accomplished by the Company.

UNDEVELOPED PROPERTIES IN MEXICO

During the past year there has been more speculative writing on the Mexican oil fields than on any other fields in the world. Correspondents at long range, seated in New York or London, fire off their big Berthas which can not win the battle, but may possibly do something to upset the morale of the interested public.

Some of the more daring writers approach as near to the activities of the oil fields as a hotel in Tampico whence they issue their lugubrious prophesies. Very few of the numerous writers have even seen Mexico, and it need not occasion surprise if their pessi-

EXUDE AT TIERRA BLANCA.

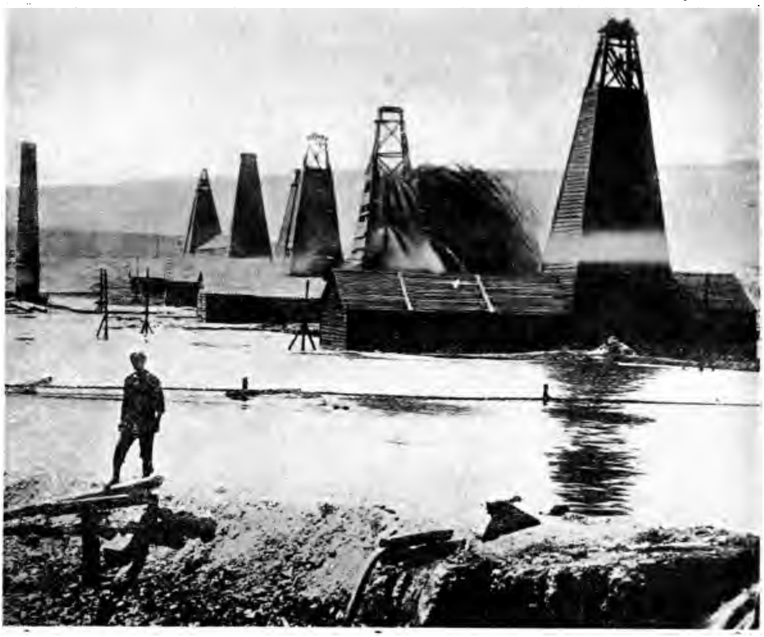
mistic conclusions are regarded with scepticism by men who have spent years in the country, and whose confidence in the future is based on intimate knowledge attained after years of painstaking investigation. A distinguished statesman, on one occasion, urged upon timid politicians the desirability of studying maps. This advice might well be applied to the oil fields of Mexico, and a

cursory glance at a map of the State of Veracruz will show how very small the proportion of the known oil lands is, which has given indications of exhaustion. The main feature which distinguishes the wise man from one who is not, is his power to discriminate between primary and secondary sources of information, whether he is studying oil lands or the civilization of the Aztecs. Unfortunately much of the literature on the Mexican oil fields that has appeared recently has not even for its basis second-hand gossip.

When the oil man speaks of pools or reservoirs of oil, he is using words in a technical sense. The oil does not accumulate in reservoirs or pools in the ordinary sense of these words, but is stored within the pores of sedimentary rocks, and the porosity of these rocks mainly determines the amount of oil stored. Sedimentary rocks in Mexico have been broken through by violent volcanic upheavals. Many basaltic dykes have been forced above the surface of the ground and there are doubtless many which give no indication of their presence on the surface. These igneous intrusions may act as walls, sealing one area of sedimentary rocks from another. At any rate, communication between the reservoir rocks is broken in many places, as the history of different fields shows.

There is much inaccurate information published about the Mexican fields. They are represented as the largest producing fields the world has ever seen, and this view has been encouraged to some extent by the unprecedented yield of individual wells. The phenomenal production of wells like Casiano No. 7, Potrero del Llano, and Cerro Azul No. 4, has led some to conclude that, because of these enormous yields, each well must of necessity have drained a huge area of territory. If we take the past output of the Russian and other fields, we shall find that the idea that large production implies the drainage of a large area is wholly unjustified. Until the end of 1910, Russia produced 1,358,176,468 barrels of oil, almost entirely from an area of less than 4,000 acres. The Maikop Field was not opened until 1911, and the production of Grosni was relatively small up till that

date. Acre for acre, the Baku fields still lead the world in production. In Emmons' book, published in 1921, on the "Geology of Petroleum," the writer says of the Bibi-Eibat field that it "covers an area of about 1,000 acres. . . The Bibi-Eibat field has produced petroleum since 1880. In 1912 it had yielded



FOUNTAIN AT BIBI-EIBAT, RUSSIA.

280,500,000 barrels." The average yield per acre of Bibi-Eibat has therefore been about 280,500 barrels. According to A. Beeby Thompson, in his "Oil Field Development" which was published in 1916, a single sand in the Maikop oil field of Russia has produced 82,500 barrels per acre. Rumania furnishes another example of an extremely rich oil field. An area of about 130 acres at Moreni has in ten years given 30,000,000 barrels, or about

225,000 barrels per acre. Galicia supplies another illustration. The Boryslav-Tustanowice oil field had prior to 1913 yielded 90,000,000 barrels of oil, and this has been taken from about 1,500 acres, or 60,000 barrels per acre. Cerro Azul has an area of about 10,000 acres, and it would require a production of over 2,250,-000,000 barrels to make Cerro Azul as productive as Bibi-Eibat. No deduction is made from this about the probable yield of Cerro Azul, but the fact is established that Cerro Azul's pro-

EXUDE AT CERRO AZUL.

duction of 94,000,000 barrels, if the conditions were similar to those of Bibi-Eibat, would not imply a drainage of more than 350 acres, or if the sands resembled Moreni, a drainage of 420 acres, and about 1,500 acres if the conditions were similar to Galicia.

Recent facts in Mexico tend to show that the idea that these large wells drain vast areas is not correct. Casiano No. 7 did *not* drain Lot 114 in Southern Chinampa, which is only a short distance to the west, and which produced during 1920-21 enormous quantities of oil. On the Cerro Viejo property, which has an area of 16,000 acres, a well with a potential production of

40,000 barrels, was drilled in on November 20, 1921. This well is south of the famous Potrero del Llano. Cerro Azul No. 4, which lies about two miles from the boundary of Toteco, should *not* be assumed to drain Toteco, or vice versa.

Vast tracts of land that have *not yet been developed* are owned by the Company, upon which the surface indications of oil are

SEEPAGE AT JUAN FELIPE.

as good as any around Cerro Azul; and until this territory has been tested by the drill, assertions about exhaustion of the properties ought to receive only the attention they merit. At one period a thorough examination was made of about 5,000 acres on the Cerro Azul property, where 7,210 active exudes were found; but the tropical growth of a few months removed every trace of the clearing necessary for this exploratory work.

To the south of Cerro Viejo lie Tierra Blanca and Chapopote Nuñez with an area of over 20,000 acres. The first well drilled at Tierra Blanca in May, 1921, had a potential production of

75,000 barrels daily; and Cerro Viejo and Tierra Blanca may be regarded as undeveloped land. No exploratory well has yet been drilled on Chapopote Nuñez. La Pitahaya, many miles north of Cerro Azul, which contains over 17,000 acres of undeveloped land, has extensive seepages. A glance at the map accompanying this volume will show the developed areas on the property owned by this Company are relatively small. It

EXUDE AT ARROYO CHICHIHUAL—LA PITAHAYA.

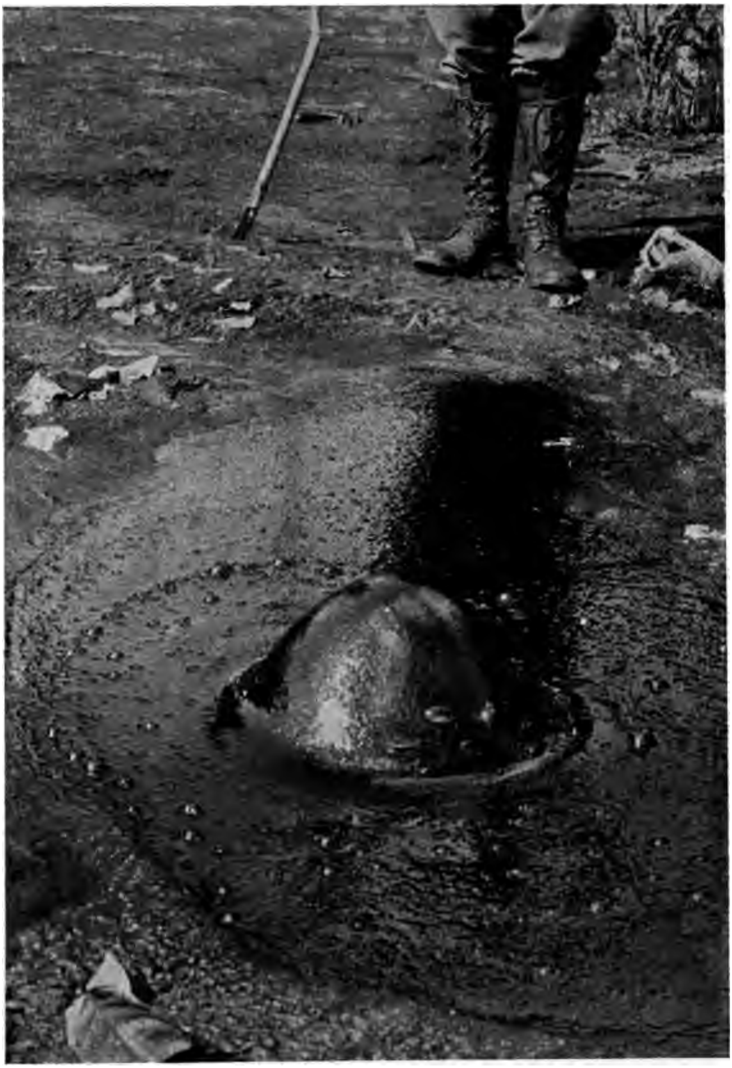
may be asked why this undeveloped land has not been tested. The answer is simple. Development at Ebano was halted in 1910, owing to the discovery of immense pools on the Huasteca property. For years Casiano No. 7 supplied all the oil that could be handled in the pipe line and refinery; and when Cerro Azul No. 4 came in, there was a shortage of tankers which could not be overcome for years owing to the war. The Company is now taking from its wells an average of over a quarter of a million barrels daily, and this oil is being produced from a very limited area. Other fields will be developed when necessary, and

the known surface indications within this undeveloped jungle land are as good as any yet discovered.

One of the best evidences of petroleum in Mexico is the active seepages, and these are very numerous on the undeveloped lands. There is no hard and fast line between a seepage of crude petroleum and a deposit of asphalt. Every gradation of sticky and inspissating oil between the two may be observed on the same

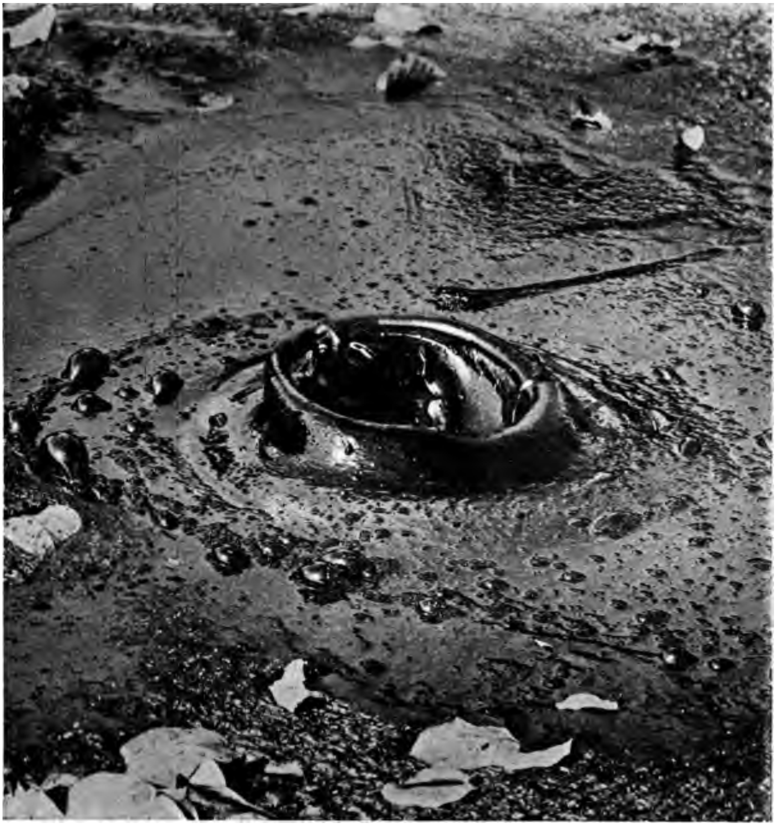
SEEPAGE NEAR CAMPECHANA.

exude. Few things are more fascinating than an excursion over one of the oil-soaked areas on the Huasteca Field. Encircling one is the jungle's growth that shuts out from view those peculiar hills of volcanic origin, near which the oil is stored. Walking over the seemingly endless beds of asphaltum, the silence is unbroken, save by a decaying stick dropping through the thick jungle, or the bursting beneath your feet of bubbles of gas that have been sealed in the hard, dry asphalt. The seepage proper is a miniature fountain, and from it there is a steady stream of oil. On either side of the continuous stream, there is a partial



A LARGE BUBBLE OF OIL ON COMPANY'S PROPERTY.

movement of oil outwards, which as the lighter oil evaporates, is converted into asphalt, and this too is of different degrees of consistency. The bubbles that appear in the seepages are of



SUBSIDENCE OF OIL BUBBLE.

varying types. In the center of an active seepage they form quickly, while in the harder parts of the deposit, one finds them unbroken, the asphalt having effectively sealed the gas. Pausing at one of the active seepages, there is evidence of movement on

its glossy, dark surface. One watches with intense interest as the imprisoned gas, seeking release, struggles with the enveloping film of oil that encases it. As this grows, the heavier, darker oil falls away, till ultimately a large, clear bubble is formed, multicolored as a rainbow, iridescent and changeful as an opal. When

BED OF ASPHALTUM, SHOWING IN FOREGROUND BONE OF BOVINE ANIMAL MIRED IN THE OIL.

it attains perfection of form and color, it trembles for a moment and then subsides—and the cycle begins again. If the deposit is semi-fluid, the developing of the bubbles is slower, and when they break, it seems to be with a weary sigh of relief.

LIST OF UNDEVELOPED OIL LANDS

The principal undeveloped lands of over 500 hectares (1 hectare=2.47 acres) owned exclusively by this Company are:

Northern Fields

	Hectares
Area del Bernal	4,356.68
Chapacao	66,118.04
Cuestecitas	38,881.09
El Cojo .	11,878.53
El Rosario	9,690.13
Guadalupe y Las Flores	18,598.78
Jopoy	2,500.00
La Azufrosa	15,593.72
La Culebra	4,481.82
Maguaves	639.46
Montaña del Gualul	7,778.58
Pors. Nos. 22 to 27 inclusive and 29 of Aldama	9,936.33
Pors. Nos. ½ 90 to 96 and 98 to 103 inclusive	9,366.27
Pors. Nos. 107 and 108 and 147 and 148, La Concepcion	3,367.80
Rayón	6,654.88
Santa Fé	1,751.87
Santa Juana	25,027.16
Santa Maria, Los Pintos, Las Yucas, Abra Hermosa and La Guajolota	83,189.61
San Vicente	20,732.85
Tancasneque	23,840.47
Tierras Blancas	5,246.94
Timas	5,353.60
Tulillo	114,528.00
Total	489,512.61

Southern Fields

		Hectares
Campechana	about	1500
Cerro Viejo and Cuchilla del Pulque (half interest)	"	7000
Chinampa	"	820
Ciruelo, Tierra Blanca, Chapopote Nuñez	"	8400
Gil de Solis	"	3900
Granadilla	"	5900
Juan Felipe	"	7500
La Merced	"	2750
La Pitahaya	"	7000
Monte Alto and Los Higueros	"	1700
Ocotepec	"	608
Pahuatatempa	"	1800
Palo Blanco	"	532
San Geronimo	"	1667
San Miguel Tres Aguas	"	1400
San Sebastian	"	750
Total	"	53,227

OIL LANDS IN CALIFORNIA

Petroleum is the most important mineral product of California, which was for many years the leading state in the Union in the production of oil. The fields extend from Coalinga to the Puente Hills.

In order to develop oil lands in California, the Pan American Petroleum Company was incorporated on September 11, 1916. The successful operation of some of the properties encouraged the directors to procure lands in other parts of California. Today the Company has properties in Kern, Santa Barbara, Ventura, Orange and Los Angeles Counties. The acreage in each county is as follows:

Kern	4,371.641
Santa Barbara	1,354.07
Ventura	19,814.58
Orange	28.90
Los Angeles	65.385
Total	25,634.576

CHAPTER IV.

THREE FAMOUS GUSHERS

CENTURIES before the sources of petroleum were reached by the drill, it was obtained from shallow pits sunk where there were exudes, and raised in buckets by a windlass, or the oil was skimmed from the surface of the water upon which it floated. Primitive methods are still employed both in Europe and Asia, and in some places in the East hand-dug wells reach a depth of many hundred feet. Such wells yield relatively a small quantity of oil and have few speculative features, but the wells drilled today by machinery have all the elements of speculation, and range from non-productive "dry holes" to "gushers." On the basis of the character of the yield they are classed as "gushing," "pumping" and "bailing." Gushers are also referred to as "fountains," "spouters," and "flowing wells." Whatever term is used to designate the gusher, it implies that the flow of the oil is due to the pressure of imprisoned forces of Nature released by the drill.

Pumping and Bailing Wells—The most common way of extracting petroleum from wells is by pumping. This is done by inserting in the well a string of tubing, at the lower end of which a pump barrel is attached. The pumps are frequently worked by a transmission system, by which a number of wells are pumped simultaneously from a central power plant; in this way the cost of production is greatly reduced.

In some oil-fields there is so much sand accompanying the oil that it is impracticable to use the ordinary pumping apparatus, and recourse is had to bailing. These bailers are long cylindrical tubes, fitted with valves at their bases, which are

lowered into the well by means of wire cables. They are used to clear the accumulated mud and sand from the bottom of the hole, and to raise the oil. When the bailer is brought to the surface, the oil is emptied into a "bailing tub" before it flows to the receptacles, where the sand is allowed to settle, prior to its removal to the main storage.

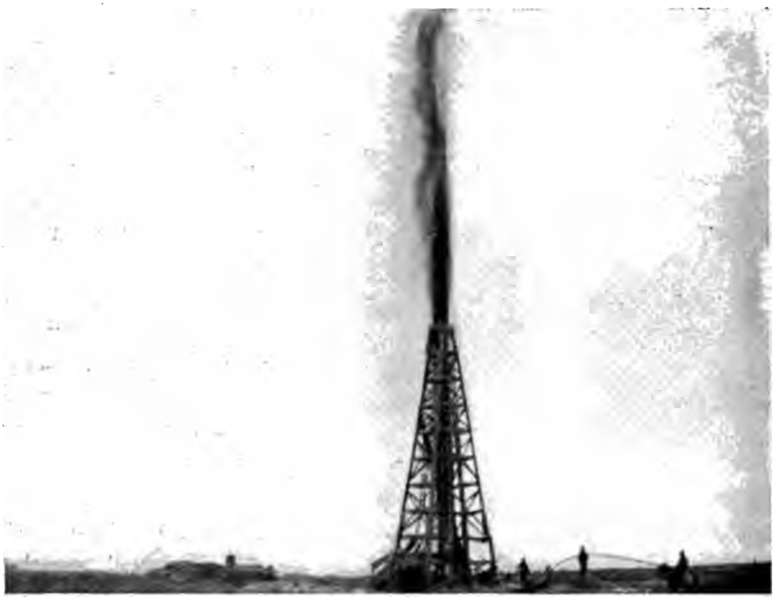
Gushers—The discovery of a new oil-producing territory is frequently announced by what is known as a "gusher." The

By Courtesy of Oil Well Supply Co.
PUMPING OIL BY HAND AT BINAGADI, RUSSIA.

oil and gas, in such cases, issue from the well at enormous pressure, and this is sometimes so powerful that the drilling tools are ejected. The oil escapes in a fountain which towers high above the derrick and drilling plant, often reducing it to matchwood, just as if a charge of TNT had been placed within the derrick and exploded.

In the early days gushers were often allowed to have full and unrestricted play, merely as a spectacle, and crowds of people made long and tedious journeys to see the wonderful phenom-

enon of oil shooting from the earth in a huge fountain. Such fountains, or "spouters," were frequent in Russia, where the loss of oil was great and the owners often ruined. Certain mechanical devices of recent invention enable gushers to be controlled, and the flow from the largest well hitherto discovered—Cerro Azul



By Courtesy of Oil Well Supply Co.
LUCAS GUSHER, TEXAS.

No. 4—is regulated with as much security and precision as a gas jet.

Baku Gusher—One of the most impressive of the earlier wells was the Droojba fountain, which Marvin graphically describes. It commenced flowing on September 1, 1883, at the rate of 40,000 barrels per day:

"The fountain was a splendid spectacle—it was the largest

ever known in Baku. When the first outburst took place, the oil knocked off the roof and part of the sides of the derrick, but there was a beam left at the top against which the oil burst with a roar in its upward course, and which served in a measure to check its velocity. The derrick itself was 70 feet high, and the oil and the sand, after bursting through the roof and sides, flowed fully three times higher, forming a greyish-black fountain, the column clearly defined on the southern side, but merging in a cloud of spray 30 yards broad on the other. A strong southerly wind enabled us to approach within a few yards of the crater on the former side, and to look down into the sandy basin formed round about the bottom of the derrick, where the oil was bubbling round the stalk of the oil shoot like a geyser. The diameter of the tube up which the oil was rushing was ten inches. On issuing from this, the fountain formed a clearly defined stem about 18 inches thick and shot up to the top of the derrick, where, in striking against the beam, which was already worn half through by the friction, it got broadened out a little. Thence continuing its course, more than 200 feet high, it curled over and fell in a dense cloud to the ground on the north side, forming a sandbank, over which the olive-colored oil ran in innumerable channels towards the lakes of petroleum that had been formed on the surrounding estates. Now and again the sand flowing up with the oil would obstruct the pipe, or a stone would clog the course; then the column would sink for a few seconds lower than 200 feet, to rise directly afterwards with a burst and a roar to 300. Some idea of the mass of matter thrown up from the well could be formed by a glance at the damage done on the south side in twenty-four hours—a vast shoal of sand having been formed which had buried to the roof some magazines and shops, and had blocked to the height of six or seven feet all the neighboring derricks within a distance of 50 yards. Some of the sand and oil had been carried by the wind nearly 100 yards from the fountain. Standing on the top of the sand shoal we could see where the oil, after flowing through a score of channels from the ooze, formed in the distance on lower ground a whole series of oil

lakes, some broad enough and deep enough to float a boat in. Beyond this the oil could be seen flowing away in a broad channel towards the sea."

On the 29th of December, 1883, the well was capped, having yielded oil variously estimated from 220,000 to 500,000 tons.

By Courtesy of U. S. Geological Survey
LAKE VIEW GUSHER, CALIFORNIA.

California Gusher—Some of the fields of the United States have furnished great gushers, and of these, few are more interesting than the Lake View gusher of California, which burst forth on March 15, 1910. This strike is due to the persistency and obstinacy of one man. The directors had decided to stop drilling and instructed the engineer accordingly, but he ignored these orders and drove the drill 47 feet deeper. His reward was an ominous rumble on March 15th, which caused the drillers to scatter quickly. Presently, there was a terrific roar accompanied

by a violent hissing, and immediately the top was blown off the derrick by a column of oil. Pieces of rock and debris were hurled into the air, and these missiles menaced the drillers, who sought shelter by escaping to a safe distance from the well. The roar and din of the eruption terrified the population for a mile around, and the oil rose to a height of 140 feet. The spray, which was swept by the wind, drenched the sage brush and saturated the ground. The inhabitants of the adjacent towns hired every type of vehicle, and hastened to witness this impressive spectacle. The greater part of the oil fell around the shattered derrick, which in a short time was isolated in a lake of oil. "Immediately the disintegrated pieces of rock ceased to be discharged, the drilling forces hurriedly strove to control the well, but the flow was so vicious that all attempts failed. Then laborers were crowded on to form additional pits and ponds to collect the flow. Three powerful pumps were brought up, and installed to lift the oil from the sump-hole, which was overflowing, into the huge tanks which had recently been completed nearby. This was the first oil to enter these receptacles, and it was fortunate that these facilities were available, otherwise heavy losses would have been incurred. The pumps had a combined capacity of 25,000 barrels a day, and by running them at full pressure they were able to keep the flow under control. As the tanks became charged, other pumps were set to work driving the oil on a journey of 150 miles from Maricopa to Port Harford, on the Pacific seaboard.

"It was only by titanic labor that the oil losses were reduced to an insignificant degree. When the gusher first broke into activity, the flow was estimated to be over 60,000 barrels per day. The initial pressure becoming expended, the well settled down to a steady flow of about 42,000 to 45,000 barrels per day for six days. Then it ceased suddenly. It had 'sanded up'—that is, the well-hole had become choked with sand and detritus. The engineers, realizing the import of this development, concluded that by pushing their arrangements forward at high speed they would be able to control the well. But they had miscalculated the

enormous forces sleeping below. In a few days the pressure of the accumulation of gases became sufficiently powerful to remove the obstruction. With a deafening report the sand was blown out, and the well resumed spouting 42,000 barrels per day."

By an ingenious device the well was brought under control, and it is said that 2,000,000 barrels of petroleum were saved during the first seven weeks. The well was intermittent in its flow; the quantity lost, however, was insignificant, owing to arrangements made in advance, and the success of the scheme for dealing with the gushing oil.

Mexican Gusher—Since the first gusher was struck in Mexico on May 14, 1901, on the property of the Mexican Petroleum Company, this country has furnished the greatest surprises in the history of oil, and Cerro Azul No. 4 is the most famous of all the fountains of this rich country. It is situated in the center of an extensive valley, which is controlled by the Pan American Petroleum & Transport Company. The yield of this well during the 24 hours prior to its being closed in amounted to 260,858 barrels, which far outstrips the history of any other well in the world.

The story of the bringing in of this well is as fascinating and as thrilling as a romance, and few things show more clearly the scientific advances recently made in mastering Nature's most explosive forces than the fact that the stupendous power of this well is completely under control.

Talbot, in his book "The Oil Conquest of the World," gives an interesting account of the method of handling a gusher many years ago, which is in striking contrast to the plan adopted when Cerro Azul was brought in.

"In the early days when a spouter got out of hand, primitive methods were adopted, and, as may be imagined, proved abortive. The well-drillers, from lack of experience and knowledge, failed to realize the immense forces of Nature. They endeavored to smother the fountain with sand and water. When this failed, a massive square shield was contrived from heavy balks of timber secured together by bolts and dogs. This was manoeuvred into

a convenient position near the well, raised on one edge, and then tipped or pulled over upon the fountain in the manner of a lid shutting a box. The surprise of the toilers, when they saw their cumbersome weighty device shot into the air like a blown egg upon a water-jet or wrenched to matchwood, may be imagined. But it brought home to them the enormous power that is present in a four or six inch solid column of oil when shot from the bowels of the earth."

SOME OF THE EMPLOYEES AT CERRO AZUL CAMP.

We have only to compare this record of a few years ago with the closing in of Cerro Azul No. 4, to realize the advances that have been made in controlling these gushers. Prior to striking the oil, elaborate and extensive preparations had been made by the Company for an expected great flow. Two 8-inch pipe lines leading from Tampico had been completed to within 50 feet of the well, and as a record of the actual work of bringing in the well was desired, the Company had a complete outfit of photographic material set up in the jungle, and a photographer employed to take photographs and moving pictures of the well.

Cerro Azul, or Blue Hill, is situated within an area of about 10,000 acres of rolling plain and hill. Before any development work had been done, it consisted of vast potreros for the grazing of cattle, and of almost impenetrable monte, where the explorer must cut his own path as he proceeds. Within this vast hacienda there are countless live asphalt springs, whose edges are white with the bones of cattle that have been mired in these seepages.

DINING ROOM AND RECREATION HALL AT CERRO AZUL CAMP, 1922.

Before the advent of the oil drillers, these were regarded as deadly traps to be shunned by the natives.

Cerro Azul is about a hundred kilometers from tidewater or any town save a few Mexican villages. Fifty kilometers of road had been carved out of the heart of the jungle, and 47 kilometers of railroad run through valley and over hill to Cerro Azul, which was an outpost of the oil industry. A derrick had been erected in the midst of the jungle near one of those basalt plugs and the well drilled to cap rock in 1915. The casing was cemented and tested to a pressure of 1,050 lbs.

and when work on the well was resumed in February, 1916, Cerro Azul No. 4 was only a name and a number on the Company's books. To the drillers it was a record of geological strata encountered and penetrated; to the Company's accountants a page of figures; to the managers an expectation; and to the other companies in the Southern Fields a source of lively curiosity.

Nothing can be more monotonous than the drilling of an oil well, unless some difficulties are encountered. Day after day two men walk into the derrick and take the place of two others who have worked for twelve hours. Within a few days this scene of ordered and ordinary activity around Cerro Azul No. 4 was to be changed to a place of tense excitement, with all the rush and hurry of a battlefield. The comparative quiet of the jungle with only the creak of the walking-beam, the muffled clang of iron on iron, and the hiss of steam, was first broken by a growling mutter, swelling at length into a menacing roar that shook the earth and was heard like the sound of distant thunder in Casiano, 16 miles distant. A little later, every leaf, every flower, every blade of grass now vivid with the greens and brilliant colors of the tropical jungle, was converted as if by magic into the fantastic dream of some futuristic painter, all a glistening black as if fashioned of highly burnished metal. In the center of this strange picture, amid the ruins of what had been a short while before a sturdy derrick of bolted timber, a column of oil many hundreds of feet high ran straight into the air, thick as a barrel, black as night, and in appearance as smooth as ebony. Cerro Azul No. 4 had come in!

The facts are few and simple. On the night of the ninth of February, 1916, a pocket of gas was struck which forced the water out of the hole through which the drilling was being conducted. During that night a cold rain set in accompanied by a heavy wind; a true "norther" was blowing up. On the morning of the tenth, work was resumed. No trained imagination is needed to picture the tenseness of the moment. That day would give to everyone the answer to his speculations, would show the

drillers the results of their industry, and would justify the judgment of the Company's experts and executives in locating and drilling this well. Every preparation had been made.

FIRST INDICATION OF OIL AT CERRO AZUL NO. 4.

Tanks were ready; two eight-inch pipe lines were laid to within fifty feet of the well. Each man knew his duties, knew what he had to do and how and when to do it. Like Von Moltke, the drilling superintendent might have said that his work was finished, and gone to bed; but, unlike Von Moltke, he

was about to deal with an unknown force, a force more powerful, more uncontrollable, more relentless than any hitherto encountered in the Mexican Fields. A half dozen strokes of the drill, and the cable went slack. The supply of gas to the boiler was immediately shut off. Presently an ominous rumbling far beneath the surface was heard, which quickly deepened in volume, and the workers fled from the derrick. Suddenly a terrific explosion took place, as if some gigantic, slumbering volcano had in a moment burst into fiendish activity. Before the drillers had stumbled fifty feet from the well, the huge drilling tools were shot into the air like a projectile fired from a siege gun; they crashed through the crown block of the derrick, reducing all the upper part to tinder, and describing an abrupt trajectory through the air, broke through the trees 120 feet from the derrick, embedding themselves sixteen feet in the earth. There they stand today, at once a monument to the relentless forces of Nature and an inspiring testimony to the ability of man to overcome great obstacles. Twenty feet from the spot where these tools—weighing about two tons—struck, a moving picture operator, employed to take pictures of the birth of the great well, was grinding his camera, and, true to the traditions of this youngest of industries, stuck to his post and kept on "cranking." His steadfastness has preserved to the Company a unique, valuable record of the birth pangs of Cerro Azul No. 4.

So uncontrollable was the rush of gas that besides throwing the tools out of the hole, it shot the cable through a ten-inch tee below the oil saver, to a distance of 600 feet, and this cable became so tangled and twisted about the head of the well that the tools as they were ejected tore the valve completely away. The gas, having swept away every restraint, and increasing in force and volume every moment, quickly wrecked the remaining part of the derrick down to the fourth girth.

Seven hours later came the oil. The industry is familiar with the pictures taken of this great gusher when at its height, but pictures do little more than suggest the terrible, the

MORE OIL.

awe-inspiring grandeur, the sublimity of the scene. No photograph can convey to the mind the power of this unrestrained force. While the men about the well were working, making preparations for an attempt to close it in, the end of a two-inch manila rope in the hands of one of the operators came over the top of the well. Instantly it was jerked from the man's hands and two hundred yards of stout hempen hawser uncoiled as rapidly as a striking rattlesnake and went spiraling up the column of oil. It was never seen again.

As the volume of oil increased, the column rose higher and higher, until on the morning of the 11th it attained a height of 598 feet, according to measurements by triangulation made by the Company's engineer. Fortunately the land around the well was of such a character that it was possible to save a great proportion of the oil, and also to measure with reasonable accuracy the amount of the flow, which, on the 19th of February had reached, as has already been said, 260,858 barrels in 24 hours. This calculation takes no account of the vast quantity of oil that in the form of spray was carried for about two miles from the well by a strong wind. The great column of oil towering into the air and swayed by the winds which blew from every quarter during the ten days of unrestricted flow literally saturated with petroleum the surrounding country for a distance of about two miles.

It is noteworthy that the well gradually increased its flow from day to day, and it is safe to assume that it had not attained its maximum when brought under control. Owing to the splendid co-operation of the various departments of the Company, more than half a million barrels of the output was saved in temporary reservoirs, into which an "arroyo" had been converted by the natives who worked with most commendable industry. As a means of calculating the flow of oil, the Company's engineer constructed several spillways about five meters in length and checked the rate at which the oil flowed per second through these spillways, also measuring the width and depth of the flow.

THE WELL AT ITS MAXIMUM FLOW BEFORE BEING CLOSED IN.
(260,858 Barrels in 24 Hours)

Precaution was taken that the level of the oil in the several reservoirs further up the creek bed did not vary while the tests were being made, the oil being allowed to flow evenly through spillways of similar capacity in each dam. A considerable time was necessarily occupied in the construction of these reservoirs, and it was February 15th before the rate of flow was first gauged. From that date until February 19th, five days inclusive, the Company's engineer gauged the flow as follows, the flow of oil on February 19th filling a space of 43 centimeters in depth by 63 centimeters in width (although the calculation was based on 40 x 60 centimeters) with a velocity of 2 meters per second:

	Barrels Daily
February 15th	152,000
February 16th	190,209
February 17th	211,008
February 18th	221,186
February 19th	260,858

No photograph could adequately portray the appearance of the men who worked at the well. Their clothes were drenched with oil until their weight became insupportable. Hands, faces, everything were a shining black. Every tool, every piece of equipment, every building within range of the well, glistened and dripped in the sun. Nor could any picture reproduce the atmosphere of the place; the mad battle against time; numberless peons working faithfully to convert the arroyos of the nearby streams into vast temporary reservoirs for the storage of oil; and the preparations already being made for the closing in of the well.

The Company's master mechanic—the late George W. Barnes—and his staff were already busy devising means to do the seemingly impossible. Hardly had the oil begun to flow when many miles to the northward draftsmen, machinists, foundrymen and blacksmiths, were working night and day upon the device that was eventually to bring the well under control. Forges glowed, and lathes turned day and night. At length the

appliance was complete and was rushed by launch to San Geronimo where a train stood ready to receive it. In a few minutes it was speeding on its way to Cerro Azul. This device consisted of heavy tongued and grooved clamps, which were to be placed on the casing. The valve and connections were fitted to the tongue and groove, and were to be moved over the well by means of a screw. It was impossible for the men to work close to the well; consequently a section of pipe 30 feet long was attached to the valve stem.

THE MEN WHO CLOSED IN CERRO AZUL NO. 4.

As a careful general calls his captains together at night to fight out the morrow's battle, so the Company's executives determined that a rehearsal would be necessary in order that each man might know his part; complicated hand signals had also to be devised, for the most stentorian voice dwindled to nothing near the roar of the great well.

The men withdrew to a point where distance deadened the bellow and there the nature and operation of the apparatus were explained to them. Painstakingly, time after time with infinite attention to detail they went over the process to be used.

On the nineteenth of February everything was ready to make the attempt. Nine days had elapsed since the well had been

VALVE PARTIALLY OVER WELL.

brought in. Speed had been used where speed was advisable, and what was more important, and a surer guaranty of success, patience had been exercised where patience was demanded. Not until the last minutiae of the effort were checked over, had the

order been given to go ahead. The table was clamped to the casing, and thirty feet away men began to turn the screw which

VALVE COMPLETELY OVER WELL.

advanced the valve slowly over the casing. It seemed impossible that any appliance devised by man could withstand that force.

THE WELL UNDER CONTROL.

Some of the men fully expected to see the heavy ironwork bent, twisted and cast aside as easily as a man doubles and discards an old pipe cleaner. But the work of the Company's experts and of its Mexican artisans was faithful, honest, unskimped work. When the valve touched the casing it held true in its place, and the body of oil was diverted slightly from the vertical. Men held their breath as they watched with anxious eyes the progress of the valve across the casing. Slowly and evenly just as at the

LEFT: TOOL EJECTED FROM WELL. RIGHT: MOUND OVER WELL.

rehearsals the men kept turning on the screw, slowly the valve moved over the casing, slowly the volume of oil continued to be deflected. The clamps still held. Now the column of oil was deflected at an acute angle to the casing, then suddenly it split into two columns—one rushing straight up again through the valve, the other bending more and more toward the 90 degree angle. Gradually the thin vertical stream became thicker and thicker, and the diverted stream thinner and thinner, until at length, the entire body of oil was rushing through the valve

straight into the air once more, no longer uncontrolled, but within the limits ordained by man. Fittings were made secure and in a short time the oil from Cerro Azul No. 4, humbled and subservient, was running into tanks, as completely under control and as accurately regulated as the water from the hydrant with which the housewife sprinkles her little flower garden.

The quantity of oil taken from the well until December 31, 1921, totalled 57,082,755 barrels. The amount of oil imprisoned here is incalculable.

The log of Cerro Azul No. 4 reads as follows:

Feet *Feet*	
0– 30	Yellow clay.
30– 35	Gravel.
35– 88	Blue shale, 15½ inch casing set at 78 feet.
88– 245	Gray shale.
245– 265	Brown shale.
265– 542	Gray shale.
542– 560	Hard brown shaly lime, showing of oil at 327 feet.
560– 655	Basalt.
655– 705	Brown shale.
705– 740	Gray shale.
740– 850	Dark shale.
850– 868	Light shale.
868– 875	Shells.
875– 890	Black shale.
890–1504	Gray shale.
1504–1616	Brown shale.
1616–1650	Blue shale.
1650–1660	Light blue shale.
1660–1705	Blue shale.
1705–1720	Light blue shale with "crystals."
1720–1723	Shell.
1723–1732	Light blue shale, with sulphur odor; 12½-inch casing set at 1728 feet 5 inches, cemented and tested to 800 pounds.
1732–1736	White limestone (top of Tamasopo); 8-inch casing set at 1735 feet 4 inches and cemented and tested to 1050 pounds.
1736–1740	Brown limestone; hole filled with cement 50 feet from bottom of casing. All connections made and shut down until February 8, 1916, when cement was drilled out and deepening began.
1740–1752	White limestone, with great flow of gas at bottom on morning of February 10th. When successfully closed on Feb. 19th, it was flowing at the rate of 260,858 barrels, as measured by Mr. Kunkel, the engineer for the Huasteca Company. Temperature of oil, 122° Fahrenheit; gravity, 21.4° Baumé. Closed-in or "rock pressure," 1035 pounds.

CHAPTER V

TRANSPORTATION OF OIL

BEFORE giving details about the transportation equipment of the Pan American Petroleum & Transport Company, a short account of the development of transportation in the oil industry may be interesting.

During the early years after the discovery of petroleum, it was transported in the most primitive way. In Burmah, Redwood tells us, oil was conveyed in vessels made of earthenware from the wells to the river and there poured into the hold of boats. In Russia the crude oil was carried in barrels on Persian carts; the body of the cart carried one barrel, and another was slung beneath the axle. At Yenanchung a crude pipe line was constructed of bamboo supported by wooden stages, which sloped gently from the well to the river. The loss by leakage was so great that ultimately it was abandoned.

Oil Creek, where oil was first discovered, was remote from the highways of commerce, and from the beginning the problem of transportation was one of great, and almost insuperable difficulty. Railways had not at that time penetrated this district, which was unpromising from the point of view either of agriculture or manufacturing. The wells, too, were often in places difficult of access, and the pathways little better than trails. The first shipments of oil from Oil Creek are said to have been made in cans carried by pack-horses. Later, wooden barrels, capable of containing 40 to 42 American gallons, hooped with iron, were used, and these were conveyed to the river by teams. The creeks and streams were utilized and around them grew up a system of transportation from the wells to the river,

and by barges down the river. The roads in wet weather became almost impassable, and the continual traffic turned the alluvial soil into mud, till "Oil Creek mud" became a by-word. The roads were often cluttered with wagons, and there was inevitable confusion and delay. The oil-boat, which permitted the shipment of oil in bulk, was a development of the new industry, but the difficulties that beset the operations of these boats were great, and militated against their general adoption. Operating them was hazardous, and when there was a freshet, the creek was jammed and accidents were frequent. The empty boats were towed up the creek by horses, and when loaded they were borne down by a freshet, or by water released after damming the stream. The conditions were such as to discourage the early operators, but with commendable doggedness they faced the difficulties and devised new schemes, out of which have gradually evolved the present efficient and economic methods employed on land and sea for the transportation of oil.

The first step towards improvement was the idea of a pipe line. The charges made by the teamsters had become exorbitant and the deliveries inadequate and uncertain. Many schemes were proposed for improving the transportation of oil but were abandoned as unpractical. The first successful plan was the laying of a pipe line by S. Van Sickle, of Titusville, in 1865. It was a 2-inch line, placed 2 feet under ground, and running from a well at Pit Hole to Miller's Farm on the Oil Creek River. This line was four miles long and on its course were three pumping stations. Vehement and insane protests were made by the teamsters, and the efficiency of the line pooh-poohed; but force and fanaticism were unequally matched against the obviously more efficient methods of Van Sickle. The capacity of the line was equal to 300 teams working 10 hours a day, and the irate teamsters did everything that jealousy could conceive to make the new plan a failure. Pipes were cut, storage tanks set on fire, and there were many acts of personal violence; but, in a short time, this method had demonstrated its superiority, and today there are about 45,500 miles of pipe line in the United

States for handling its annual production of about 450,000,000 barrels. This seemingly bewildering network of trunk and branch lines is economic, efficient and simple. The oil is forced through the pipe lines by pumps, and pumping stations are erected at definite points. At each station the oil is received in one or more tanks, and from there it is pumped to similar tanks at the next station. Impurities in the oil tend to choke the pipe lines, which are kept clean by a device known as a "go-devil."

ONE OF THE 1,220 TANK CARS OWNED BY THE COMPANY.

This is a spindle with blades, which rotates rapidly, and is forced through the pipe by the current of oil. The "go-devil" scrapes the sides of the pipe line as it speeds along from station to station.

The expansion of the oil industry, and the consequent demand for increased transportation, was met to some extent by the railways, which saw in this new industry an additional source of revenue. At first, the oil barrels were conveyed on ordinary freight cars, which entailed considerable loss of space. Skeleton wagons were afterwards built, with racks for the barrels. In 1865, a species of tank was constructed and

placed on flat cars. Most of these tanks were made of wood, tub-like in shape, and hooped with iron; they were rather smaller in diameter at the top than at the bottom. These flat cars were fitted with two tanks, each having a capacity of forty to fifty barrels; they were called "rotary oil cars." The builders and designers of these cars, with characteristic progressiveness, soon improved their design and construction, and the newer patterns eliminated the great loss of oil from leakage, which had hitherto been a serious drawback; some of the cars had a very ingenious gate-valve which could only be opened by a specially designed wrench. In 1871, these were replaced by tanks of boiler-plate, similar to those now in use. Modern tank cars are

TRAIN OF TANK CARS IN NEW ENGLAND.

built capable of carrying 10,000 to 12,500 gallons; they are horizontal and cylindrical in shape and have slightly convex ends. These tank cars are surmounted by a dome, similar to that of a steam boiler, which provides for the expansion of the oil; there is an opening, or man-hole, at the top of the dome for filling; and there is a valve at the bottom of the tank for discharging. The loading rack consists of a raised platform, built between two tracks and extending along the side of the railway for a distance of the maximum length of the tank train. The loading rack is about the same height as the top of the tanks. The pipe line is placed on a raised platform, with vertical branches rising at intervals equal to the distance of the domes between the neighboring tanks. The vertical branch is furnished with a valve, and an adjustable spout or sleeve for placing in the

opening in the tank dome. Refineries have sidings laid down for the tank cars, and a train load of these can be filled with oil in a very short time.

The problems of sea transportation were similar to those on land. The demand for speed and economy of space ultimately led to the construction of the modern tanker. In 1886, the petroleum exported from the United States was shipped in barrels, each containing 42 gallons. The weight of the barrel was 64 pounds, or about one-fifth of the weight of the oil. It was impossible to pack these on a vessel without great loss of space. In addition, the barrels were expensive as they had to be carefully made, so as to avoid leakage, and they were usually sold after arrival at port at a great discount. But this method of exporting oil was too costly and wasteful to commend itself to exporters. Bulk shipment had solved the difficulties of domestic transportation, and it was logical to apply the same method to the export trade. Slowly there has evolved from the barge used at Oil Creek, the modern steel tanker divided into separate compartments by longitudinal and transverse bulkheads, and capable of carrying 10,000 to 15,000 tons of oil as safely as any other kind of cargo.

The tank vessel has been the most important invention in the shipment of petroleum. Storage tanks for receiving the oil from tankers are now almost as familiar a sight in the ports of the world as the crane. Tank steamers are fitted with wireless, and the port of discharge or loading is notified of the vessel's arrival. As soon as the tanker is tied up, pumps are started, and, simultaneously with obtaining provisions for the next voyage, the oil is being loaded or discharged.

Modern tankers are so constructed that fuel-oil is carried with much less risk today than a cargo of coal. It is popularly supposed that oil is a very risky commodity to handle, but the very decided difference between the rates asked by insurance companies on a cargo of fuel-oil and a cargo of coal proves how they view the matter. The cost between the United States and Great Britain on fuel-oil is about 25% less than on coal.

A short description of the cargo tanks in a tank steamer may be given from Captain White's book on oil tank steamers:

"A tank steamer is one which, as its name denotes, is divided into tanks. It is divided by a longitudinal bulkhead at the middle line through the whole length of the cargo part of the vessel, the bulkhead, extending from the tank bottom up to the deck. The vessel is also divided by athwartship bulkheads, which extend from one side of the ship to the other, thereby forming the tanks.

"In large modern tankers, there are generally twelve double tanks, two pump rooms, and two cofferdams.

"Starting right forward in the ship, there is first the fore peak with a watertight bulkhead at its after end. Next abaft this, is the fore hold, which is intended for any cargo the vessel is to carry besides oil.

"At the after end of the fore hold is an oiltight bulkhead, extending from side to side, and from the bottom of the ship up to the deck above. This cuts off the fore hold from the oil tanks. Abaft this bulkhead, and five feet away, is another oiltight bulkhead similar in construction, these two bulkheads making an oiltight space which is called a cofferdam. This cofferdam is filled with water, thus making a solid body of water between the fore hold on the forward side of the cofferdam and the oil tank on the after side of the cofferdam.

"There is a small pump room for this forward section of the ship, which is for this section of the ship alone. The small pump it contains deals with the fore peak, the fore deep tank (which is situated under the fore hold) and the cofferdam. Thus the forward section of the ship is entirely isolated from the oil cargo tanks.

"The cargo tanks are conveniently numbered from aft and run from 1 to 12; so the forward tank is called No. 12 port and No. 12 starboard. This is the tank next abaft the cofferdam which has already been described.

"Coming aft from No. 12 tank, we have tanks 11, 10, and 9. On the after side of No. 9 tank we usually have the forward

pump room. It contains two big cargo pumps, one on the port side and another on the starboard side. The after bulkhead of No. 9 tank, which forms the pump room forward bulkhead, and the after bulkhead of the pump room, which forms the forward bulkhead of No. 8 tank, are oiltight, thus making an oiltight compartment between No. 9 and No. 8 tanks.

"Proceeding aft, we have the tanks 8, 7, 6, and 5, and on the after side of No. 5 tank we have the after pump room. This is similar in construction to the forward pump room, and also has two big cargo pumps and an air pump, the after bulkhead of No. 5 tank forming the forward bulkhead of the after pump room, and the forward bulkhead of No. 4 tank, forming the after bulkhead of the after pump room.

"Continuing aft, we have tanks Nos. 4, 3, 2, and 1. On the after side of No. 1 tank is an oiltight bulkhead, which is pierced by the pipe line on the port side only; this really finishes the oil cargo tanks.

"The next tank abaft No. 1 is generally known as the cross bunker tank, which is used by the engineers as bunker space. At the after end of this cross bunker tank is an oiltight bulkhead extending from side to side and from the tank bottom to the deck above, and at a distance of five feet further aft is a similar bulkhead. The space between these two bulkheads forms the after cofferdam, which is filled with water, thus making a five feet thick bulkhead of water between the tanks on the forward side and the stokehold on the aft side. Thus the stokehold and engine room (which is abaft it) are absolutely shut off from the tanks containing oil.

"The question naturally arises, 'How do you stop the oil from rolling, even though each tank has its longitudinal bulkhead at the middle line?' This is effected by filling the oil up into the expansion trunk of the tank. The expansion trunk could almost be correctly called 'the contraction trunk,' seeing that it is the smallest part of the tank. It is formed by the summer tanks in the following way:—In each tank, and out in the side, is built another small tank close up under the deck, and extending about

15 feet from the ship's side towards the middle of the ship. It is about 8 feet in depth, and runs the whole length of each tank fore and aft. To describe it by name it could be correctly called 'a wing tank,' from its situation up in the 'wings' of the main tanks. It is entirely separate from the main tank in which it is situated, and has its own little hatches, opening up to the deck above, and also its own pipe line arrangements. Thus it will be seen that from the top of the main tanks to a depth of at least 8 feet down (which is the level of the summer tank bottom) each main tank is reduced in breadth by 15 feet, owing to the presence of the summer tanks. This, the smallest part of each main tank, is called 'the expansion trunk.' When the main tanks are loaded it is always the rule to fill them at least up into the expansion trunk some four or five feet. Thus below the expansion trunk is a solid body of oil, which therefore cannot roll. The only quantity which can roll is the small quantity in the expansion trunk.

"The expansion trunk of a tank is never filled right up to the top, but usually there is a vacant space between the top of the oil and the top of the tank. The measurement of this space is called the 'ullage.' When oil is at a higher temperature it expands, and when its temperature falls it contracts, so a vacant space is left at the top of the tank when loaded to give room for the oil to expand. Thus does the top part of the tank derive the name of 'expansion trunk.'"

The Pan American Petroleum & Transport Company's Fleet of Steamers—No single fact could give a clearer idea of the development of the Company than a history of the growth of its fleet. The sale of oil to railways whose termini were remote from the Ebano and Huasteca fields, and to customers beyond Mexico, raised the question of new methods of transportation, and in October, 1911, the *Snowflake,* of 1,726 tons, was chartered for one year from the Trinidad Lake Petroleum Company. In April, 1912, the *Russian Prince,* of 5,800 tons, was chartered for a period of two years from the Interocean Transport Company, and was delivered about the time the charter of the *Snowflake*

had expired. The sailing of the *Snowflake* on her first trip marked an epoch in the history of the Company. It was the beginning of expansion beyond the shores of Mexico; and from a vessel of 1,726 tons a fleet of tankers has grown, till today the Company owns 272,493 tons, with a cargo capacity of 1,798,500 barrels.

The development of the present large fleet of tankers was due to two factors: first, the discovery of an immensely productive

FIRST SHIPMENT OF OIL IN MAY, 1911, FROM THE HUASTECA FIELDS PER S.S. "CAPTAIN A. F. LUCAS."

field of oil south of the Panuco; second, the necessity of establishing outside of Mexico, stations where a ready market for the oil could be found. Productive wells in the Mexican jungle represented only potential wealth; and the problem of transporting the oil from the fields to customers could only be solved by building tankers. In preparation for what the management regarded as a large new field for the sale of oil, six tankers were ordered, and the first of these was delivered in 1912, and named after the general manager, *Herbert G. Wylie.* The remaining

S. S. "HERBERT G. WYLIE," 6,620 TONS.

five were delivered in 1913. Almost all the tankers have been named after officials and others closely identified with the Company. The names of the tankers built in 1913 are: *C. A. Canfield, Norman Bridge, Charles E. Harwood, Edward L. Doheny,* and *J. Oswald Boyd.*

It needed years to convince managers of steamship companies and stationary plants that Mexican fuel-oil was more efficient than coal. The Sales Department of the Company worked arduously and persistently for years, under the most depressing conditions. The discovery of oil in Mexico was new, the quality of the oil was unknown, and doubts were cast upon the possibility of maintaining production. The bringing in of new wells of unprecedented yields was listened to with scepticism. Fuel-oil was offered at most tempting rates, and ultimately a firm in New England undertook to give it a trial. This was the beginning of an activity which has continued with increasing rate to the present time. The new uses of oil in every form in the European War, and the recognition of its enormous importance in all fields of war activity, awakened the world to a realization of its significance. No one today asks for proof as to the superiority of oil over any other fuel. The sale of oil has become a question largely of supply and demand, like any other commodity; and each year the chemist discovers some new use for, or new commodity obtainable from the crude oil, till the number of products obtained from oil amounts to many hundreds.

A market for Mexican oil was found in the United States and in South America; and the oil was transported in the six new steamers owned by the Company. The railroad to Cerro Azul was completed in 1914, and several wells were drilled; owing to the unsettled political conditions prevailing in Mexico, none of these wells was completed until February, 1916, when the outlook appeared more favorable.

An increasing demand for more oil had arisen in the meantime, and the management instructed the completion of Cerro Azul No. 4.

Prior to 1916 two additional ships had been ordered to meet

S. S. "WILLIAM H. DOHENY"—10,206 TONS.

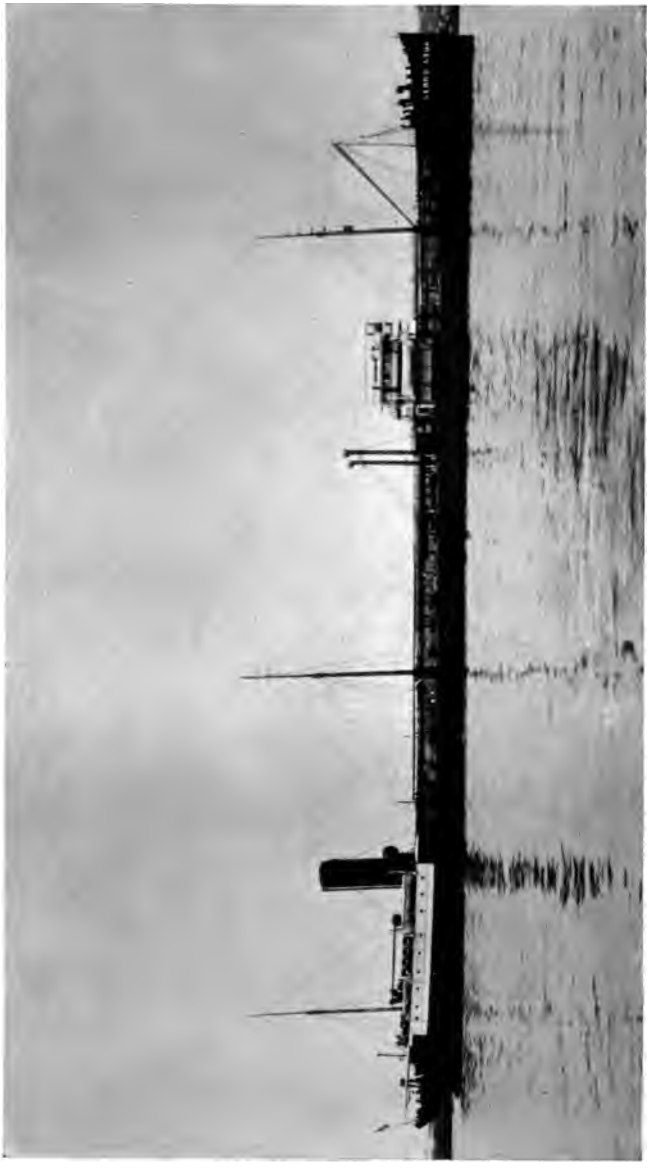
the expected large production of Cerro Azul No. 4. It was realized that a pressure of 1,050 lbs. per square inch implied a great flow of oil, and the drilling in of this well almost syncronized with the delivery of two new tankers, the *Oscar D. Bennett* and the *J. M. Danziger,* adding 17,900 tons to the existing fleet. The unparalleled yield of this well necessitated additional tankers, six of which were completed in 1917. These vessels are: *Edward L. Doheny, Junior, Harold Walker, George G. Henry, William Green, Frederic R. Kellogg,* and *Frederic Ewing.*

Before the European War ended there was no necessity to advocate the advantages of fuel-oil, and there sprang up for it a world-wide demand. The management increased the refinery and pipe line, and added during 1918 six ships to the fleet: *S. M. Spalding, Paul H. Harwood, George W. Barnes, Mexoil, W. L. Steed* and *E. L. Doheny, Third.* The collapse of the German army late in 1918 lessened for a time the rate of increase in demand which had marked 1917 and 1918.

The *Fueloil, Panoil* and *Dean Emery* were added to the fleet in 1919. It was realized, however, that as soon as the oil in storage had been absorbed further transportation facilities would be needed by the Company, and in 1920 six vessels were delivered: *Crudoil, I. C. White, Elisha Walker, William H. Doheny, Franklin K. Lane,* and *Crampton Anderson.*

The delivery of the Company's two largest vessels in 1921 completes the fleet at present constructed. These two tankers were named after two hills which are intimately associated with the Company's successful exploration for oil in Mexico: *Cerro Ebano,* and *Cerro Azul.*

For clearer reference, there is appended a complete list of tankers, showing the date of delivery of each vessel, tonnage, length between perpendiculars, beam, and the mean summer draft when loaded. The building up of this fleet is the work of ten years, and perhaps more clearly than any other factor indicates the strength and resources of the Company:



S. S. "CERRO AZUL" 12,940 TONS.

Name of Tanker	Date	Tonnage	Length	Beam	Draft
Herbert G Wylie	1912	6,620	360′0″	50′2″	22′8″
Norman Bridge	1913	6,885	365′0″	50′3″	22′11″
C. A. Canfield	1913	9,850	405′0″	55′0″	26′2″
Edward L. Doheny	1913	9,970	415′0″	54′6″	26′1″
Charles E. Harwood	1913	5,100	320′0″	45′0″	22′2″
J. Oswald Boyd	1913	2,770	245′0″	44′0″	15′11″
Oscar D. Bennett	1916	7,550	392′0″	51′4″	24′3″
J. M. Danziger	1916	10,350	430′0″	58′0″	25′8″
Edward L. Doheny, Junior	1917	12,775	468′6″	62′6″	27′0″
Harold Walker	1917	10,350	430′0″	58′0″	25′8″
George G. Henry	1917	10,200	435′0″	56′0″	25′10″
William Green	1917	10,350	430′0″	58′0″	25′8″
Frederic R. Kellogg	1917	10,100	425′8″	57′0″	25′5″
Frederic Ewing	1917	10,350	435′0″	56′0″	26′0″
S. M. Spalding	1918	10,200	435′0″	56′0″	25′10″
Paul H. Harwood	1918	10,200	435′0″	56′0″	25′10″
George W. Barnes	1918	9,100	415′0″	56′0″	25′4″
Mexoil	1918	2,400	246′6″	37′9″	16′0″
W. L. Steed	1918	9,100	415′0″	56′0″	25′4″
E. L. Doheny, Third	1918	12,775	468′6″	62′6″	27′0″
Fueloil	1919	2,400	246′6″	37′9″	16′0″
Dean Emery	1919	10,600	430′0″	59′0″	25′7″
Panoil	1919	2,400	246′6″	37′9″	16′0″
Crudoil	1920	2,400	246′6″	37′9″	16′0″
I. C. White	1920	10,600	430′0″	59′0″	25′7″
Elisha Walker	1920	10,600	430′0″	59′0″	25′7″
William H. Doheny	1920	10,206	435′0″	56′0″	25′10″
Franklin K. Lane	1920	10,206	435′0″	56′0″	25′10″
Crampton Anderson	1920	10,206	435′0″	56′0″	25′10″
Cerro Ebano	1921	12,940	480′6″	65′9″	26′11″
Cerro Azul	1921	12,940	480′6″	65′9″	26′11″

In addition to the above 31 tankers, the Pan American Petroleum & Transport Company, through its subsidiary, the Huasteca Petroleum Company, has on charter the following tankers:

Name of Tanker	*Tonnage*
MANTILLA	8,400
MELINE	10,360
MENDOCINO	10,360
MIRLO	10,100
MONTANA	10,360
NORA	14,308

The Pan American Petroleum & Transport Company has a half interest in the tankers owned or chartered by the British Mexican Petroleum Company, Limited. This latter Company, formed in 1919, owns the following steamers:

Name of Tanker	*Tonnage*
INVERARDER	8,685
INVERLEITH	10,300
INVERURIE	10,300

This Company has now four steamers under construction and four steamers chartered from the Huasteca Petroleum Company, and the following from Andrew Weir & Company:

Name of Tanker	*Tonnage*
CALORIC	10,270
GYMERIC	9,500
OYLERIC	9,530
WYNERIC	6,930

ONE OF COMPANY'S TRUCKS DELIVERING OIL IN NEW ENGLAND.

Land Transportation—The oil from the wells in Mexico is transported to the storage tanks at Terminal and Tankville by means of pipe lines. Several of the distributing stations in North and South America have tank cars and trucks. The total number of tank cars owned by the Company is 1,220, the majority of which have a capacity of 10,000 gallons. For the delivery of oil to local customers the Company in North and South America has in operation 69 trucks with an average capacity of about 1,500 gallons.

WHAT TONNAGE MEANS

In Shipping terminology the word *tonnage* has general and specialized uses. In a general sense, "tonnage" is a collective term like "bottoms," denoting a number of ships; it is also employed in such phrases as "cargo tonnage" to indicate the gross and net cubic capacity of a vessel. In a specialized sense, tonnage has five principal meanings:

1—DISPLACEMENT TONNAGE is the *total weight in long tons of a vessel and its contents,* and is so called because this weight is precisely identical with the weight of water displaced by the immersed part of the vessel.

2—GROSS TONNAGE expresses the *total capacity of a vessel's closed-in spaces.* It consists of the sum of the following items:

- (a) The cubic capacity of the vessel below the Tonnage Deck (The *tonnage deck* is the upper deck in all vessels which have fewer than three decks and is the second deck from below in all other ships.)
- (b) The cubic capacity of enclosed spaces between decks above the tonnage deck.
- (c) The cubic capacity of the permanent closed-in spaces on the upper deck available for cargo or stores or for the berthing of passengers or crew.
- (d) The "excess of hatchways": The capacity of these spaces is determined in cubic feet and the total capacity is then divided by 100.

This figure of 100 is arbitrary but arbitrary with a reason. If a cargo consists of tuns of wine, every ton of such cargo will occupy about 100 cubic feet; if cargo consists of cork it will occupy from 150 to 200 cubic feet; if of wheat, 40 cubic feet; if of pig iron, 10 cubic feet. Cargoes vary in cubic space per ton; but for the purpose of fixing port and dock charges and collision damages, the Official Standard Measuring Figure is taken as 100 cubic feet per ton.

3—UNDER-DECK TONNAGE is the total capacity in tons (1 ton= 100 cubic feet) of the space below the tonnage deck.

4—NET TONNAGE expresses the capacity of a vessel's closed-in spaces less certain deductions allowed for propulsion, accommodation of crew, and navigating purposes; and in a general sense represents the spaces available for accommodation of passengers and crew.

(Gross and net tonnages are used chiefly for calculating port, wharf, canal or pilotage dues, and vary with the varying marine and shipping laws of different nations and for Suez and Panama Canals).

5—DEADWEIGHT TONNAGE (or more correctly deadweight capacity) denotes the *weight of cargo, bunkers, stores and crew a vessel can safely carry.* In other words it is the difference between the number of tons (2,240 pounds) of water a vessel displaces "light" or unloaded and the number of tons it displaces when submerged to load water line.

It is obvious there can be only a vaguely indefinite ratio between displacement tonnage on the one hand and gross, net or deadweight tonnage on the other; and merely an approximate ratio between gross, net and deadweight tonnages. The latter ratio is determined by the fairly constant proportion of space required for propulsion and navigation and by the fact that the measuring allowance of 100 cubic feet will accommodate 2½ times the space occupied by an average commodity, viz: 40 cubic feet per ton.

CHAPTER VI

DISTRIBUTING STATIONS IN THE UNITED STATES, CANAL ZONE, SOUTH AMERICA AND GREAT BRITAIN

STATIONS IN THE UNITED STATES

THE Pan American Petroleum & Transport Company, through two subsidiaries, the Mexican Petroleum Corporation, and the Mexican Petroleum Corporation of Louisiana, Incorporated, has a chain of stations at the principal ports on the Atlantic and Gulf of Mexico from Portland, Maine, to Galveston, Texas.

For years the Sales Department of the Company worked in New England with persistent perseverance, without being able to induce a single industrial plant to try Mexican fuel oil. Coal under boilers New England manufacturers knew, but oil was an unknown quantity. New England was the first point of attack by the Company, because of its importance in the industries of the United States. It is one of the greatest centres of industry in the world, more especially in the manufacture of textiles, boots, paper, automobile tire fabrics, and rubber goods. Mills are equipped with the most modern machinery, and the value of all factory products in New England forms a large proportion of the total for the entire country. A circle around Providence, R. I., of thirty miles' radius, has many millions of spindles. The Jenckes Spinning Company was led to make a trial of fuel oil, which immediately convinced the owners of its superiority.

The success in one plant led to its trial in others; and today there are hundreds of factories with fuel oil installations, which

in addition to many other advantages has enabled them materially to increase their output. During the year 1914 the total sales of the Mexican Petroleum Corporation in the United States amounted to 85,000 barrels; in 1921, the sales in the United States exceeded 20,000,000 barrels.

When the United States Government proposed an import duty on foreign petroleum, the fuel administrator for Massachusetts published a document, on October 25, 1921, pointing

STATION AT PORTLAND, MAINE.

out that this would mean an increase in the fuel bill of the industries in New England of $5,000,000. It is impossible, owing to prohibitive freight rates, to obtain supplies from the oil fields of the South and West, so that New England manufacturers are dependent for the successful operation of their business on oil from Mexico.

Portland, Maine—The United States War Department is preparing a series of booklets on the ports of the country, and in the first one of these, which deals with Portland, the writer says: "The only plant available for oil bunkering of large vessels is that of the Mexican Petroleum Corporation. This plant is on the South Portland side of Fore River, below Vaughan's Bridge,

and a channel 28 feet deep is kept open and the largest vessels bunker here by taking advantage of the tide."

Portland is on the westerly end of Casco Bay, and is the most northerly and easterly port on the Atlantic coast in the United States. The harbor is three and a half miles from the sea, and is well protected. It is the nearest port in the United States to Great Britain and Europe, and its geographical situation is most favorable for marine traffic. The distance from Portland to Pernambuco is practically the same as from New York. Portland is the main outlet for Canadian grain, which is carried by the Grand Trunk Railway. There is a large coastwise and foreign trade with the port, and the White Star, Cunard, Anchor, Furness-Withy & Co., Cairne, Thompson, and other lines operate between British ports and Portland. Within the city itself there are more than 300 industrial plants.

The Mexican Petroleum Corporation's property in the city was purchased in 1915, and covers an area of 57.10 acres, on which have been erected seven tanks with a total capacity of 365,500 barrels. The Corporation operates trucks for the supply of local customers, and tank cars for conveying the oil by rail to plants outside the city.

Boston, Massachusetts—The city of Boston is on Massachusetts Bay. To the north is the Charles River, which widens at Boston into a broad inner harbor or back bay. The harbor affords nearly sixty square miles of anchorage, and is studded with numerous islands. The channels afford a clear passage of 27 to 35 feet. The city is fringed with wharves. In 1920 Boston was fifth in the United States in the total value of its foreign trade, being exceeded only by New York, New Orleans, Philadelphia and Galveston. In imports alone it occupied second place. The total value of imports and exports was $584,544,985. The leading countries with which business is done are Great Britain, Egypt, Cuba, Argentina, Uruguay, Australia, Belgium, Germany, Italy and British South Africa. The chief exports are meat and dairy products, leather, iron and steel, cotton, paper, woolens, fruit and nuts.

The Mexican Petroleum Corporation has a station at Chelsea near Boston. The property was purchased in 1916 and is 24.895 acres in extent. On this have been built, in addition to pump house and offices, six tanks of 55,000 barrels each making a total storage of 330,000 barrels. To accommodate customers in the

STATION AT BOSTON, MASS.

manufacturing towns near Boston, the Corporation owns many tank cars. Delivery of oil in the city and neighborhood is made by trucks; and barges deliver oil for bunkers. During 1921 the Corporation sold at Boston 2,452,070 barrels of oil.

Providence, Rhode Island—The city of Providence is built at the north end of Narragansett Bay, thirty miles from the sea. It ranks tenth amongst United States seaports in tonnage

and value of cargoes. It is the center of one of the largest manufacturing districts in New England, and is the natural distribution point for the trade carried on in the city and surrounding country. The coastwise trade to and from Providence is very large, and there is ample accommodation and safe

STATION AT KETTLE POINT, PROVIDENCE, R. I.

anchorage in the port for merchant ships. A channel more than thirty feet deep at low water leads from the docks to the open sea, and there is communication by rail to all the principal business and manufacturing centers of New England.

The chief industries include the making of machinery, mechanical appliances, silverware, jewelry, cotton, silk and woolen fabrics, and fire protection apparatus and appliances.

The Mexican Petroleum Corporation has two stations in Provi-

dence, one at Allens Avenue and the other at Kettle Point. A plot of land 7.767 acres in extent was obtained in 1915 at Allens Avenue, and during the same year another plot of land, of 40.71 acres, at Kettle Point. On the Allens Avenue property there have been erected two tanks, one of 37,500 barrels capacity, and the other of 55,000 barrels. In order to supply oil in the city and surrounding districts from this station many trucks are operated by the Corporation. At Kettle Point four 55,000 barrel

STATION AT FALL RIVER, MASS.

tanks have been erected. Tank cars and trucks are owned by the Corporation for the conveyance of oil to customers in and beyond the city. The total sales of oil during 1921 amounted to 3,359,654 barrels.

Fall River, Massachusetts—Fall River is the eastern terminus of the old Fall River Line, and handles a very large coastwise traffic. 943 vessels of over 500 tons cleared the port of Fall River during 1920. The total tonnage of all vessels entering the harbor was 3,848,726. The chief industry is the manufacture of cotton textiles, in which it occupies the premier place in

the United States. The city has 111 cotton mills, a number of which have recently been converted from coal to oil. The factories contain over 4,000,000 spindles.

In 1919 the Mexican Petroleum Corporation obtained two tracts of land, the combined area of which is 10.077 acres. On one of these tracts has been built a tank of 55,000 barrels. The supply of oil locally is made by trucks.

STATION AT CARTERET, PORT OF NEW YORK.

Carteret, Port of New York—This station is about five miles from New York, the largest port in the world. The number of vessels engaged in foreign trade which entered the harbor during the year 1920 was 5,283, representing a total tonnage of 17,404,188, which is almost double the tonnage of 1905. The import and export trade of the port is colossal. The total foreign imports during 1920 amounted to $2,892,621,089, and the exports for the same period totalled $3,383,688,048. The variety of the products handled in New York is legion. Goods

are shipped from New York to every part of the world and produce from every country is imported.

An increasing number of vessels are using oil, and a large proportion of the business of the Corporation at Carteret is the bunkering of vessels at New York. The land at Carteret, pur-

STATION AT PASSAIC, PORT OF NEW YORK.

chased in 1915, covers an area of 337.12 acres. Eight tanks of 55,000 barrels each have been erected on the property. The Corporation owns six oil barges, two of which are self-propelled; the remaining four are towed by the "Mexpet," the first oil-burning tug in New York Harbor. Oil is delivered beyond the city in tank cars, of which there are over 100 attached to this station. The total amount of oil from the Company's Mexican fields delivered in New York in 1921 amounted to 5,471,744 barrels.

Passaic, Port of New York—Passaic is on the Passaic River, about twelve miles from New York, and is within the Port of New York Authority district. It is the business centre of a

district with a population of 130,000, and has a great number of industrial plants, manufacturing a variety of textiles, rubber goods, metal products, artificial leather, parchment paper, oil cloth, automatic weighing machines, structural steel, etc.

The Mexican Petroleum Corporation purchased 6.22 acres in 1919, and on this have been erected two 55,000-barrel tanks. The oil is brought from Mexico to New York Harbor, and thence shipped by barge to Passaic.

CONSTRUCTION OF STATION AT BALTIMORE, MARYLAND.

Baltimore, Maryland—The city of Baltimore is built on the Patapsco River, about twelve miles from Chesapeake Bay, and 172 miles by water from the Atlantic Ocean. The ship channel is 35 feet deep and 600 feet wide. The port is fitted with the most modern equipment for the handling of grain, coal, oil, sulphur, fertilizers, and other specialized shipments. The city is served by several railway systems. There are 42 steamship companies for foreign service with offices in Baltimore, and in addition the ships of 15 lines ply between the city and the principal ports on the Atlantic and Pacific seaports. The principal imports are bananas, fertilizers, manganese ore, nitrate of soda, copper, oil, wood pulp, chemicals, china and earthenware. The value of the imports in 1921 amounted to $41,124,328. The chief exports are automobiles, copper, coal, corn, flour, wheat, rye, iron and steel manufactures, lard, machinery, oil, starch,

lumber, tallow and tobacco. The value of the exports in 1921 was $142,463,744. The net tonnage of vessels entering was 5,809,817.

The Mexican Petroleum Corporation purchased 86.39 acres of land in 1919 on Curtis Bay, which is about five miles from Baltimore. Eight tanks of 55,000 barrels each are being erected. Bulkheads and piers are under construction, and a slip is being dredged to accommodate the largest of the Company's tankers.

Norfolk, Virginia—The city of Norfolk is built on the northern side of the Elizabeth River, an arm of the Chesapeake Bay.

STATION AT NORFOLK, VIRGINIA.

It lies within Hampton Roads. The harbor is capable of accommodating more than 3,000 ships. Forty-five steamship lines carrying general cargo and twenty lines carrying coal cargo serve the port in foreign trade. There are eight trunk line railroads with terminals in the city. The port is equipped with every modern facility for handling merchandise. Norfolk has an extensive import and export business. The exports during 1921 amounted to $173,345,428 and the imports to $4,340,239. Hampton Roads occupies the first place in the United States as a shipping port of tobacco, and coal and cotton are exported in great quantities. The shipments of tobacco in 1921 amounted to $141,864,799. The number of vessels enter-

ing and clearing in 1914 was 1,733; during 1921 the number increased to 4,822. The total tonnage entering and clearing Norfolk and Newport News during 1921 was 12,508,360.

In 1917 the Mexican Petroleum Corporation purchased 79.26 acres of land at Norfolk. On this have been erected eight tanks, six of 55,000 barrels each, one of 38,000, and one of 35,500, making a total of 403,500 barrels.

STATION AT JACKSONVILLE, FLORIDA.

Jacksonville, Florida—Jacksonville is built on the St. Johns River, 18 miles from the open sea, with a channel 30 feet deep from the Atlantic to the docks. In front of the municipal docks the river is over a mile wide, and provides about three-fourths of a square mile of thirty-foot anchorage for steamers. There are regular sailings to Europe and South America, and a large coastwise traffic to ports on the Atlantic and Pacific seaports. The exports of Jacksonville consist chiefly of naval stores, hard phosphate rock, lumber, cross ties and cotton. The chief im-

ports are kainite, nitrates and other fertilizer fillers, in addition to large consignments of refined and fuel oils. 97 vessels entered and cleared during the month of October, 1921, with an aggregate tonnage of 185,240, of which 31,886 tons were of foreign register.

The Mexican Petroleum Corporation obtained in 1916 a site for the building of an oil station, the area of which is 16.8

STATION AT TAMPA, FLORIDA.

acres. The terminal is situated on the St. Johns River; and there have been erected on the property three tanks of 55,000 barrels each.

Tampa, Florida—The city of Tampa is built about 35 miles from the open sea, with a good, well-sheltered harbor. The channel is 24 feet deep, and Government dredges are at work increasing this to 27 feet. The phosphate industry is the most important in the neighborhood of Tampa. It is estimated that 80% of the supply of phosphate in the United States is in Florida, a large proportion of which is within Tampa's commercial territory. The next important industry is timber, and 40,641,680 feet of timber were shipped from the port during

1920. The chief imports are oil and cocoanuts. Tampa is noted for its cigars, in the manufacture of which more than 150 factories are engaged. The phosphate mines use large quantities of fuel oil.

The Mexican Petroleum Corporation began work at Tampa in 1915, and acquired 22.132 acres of land, upon which have been erected three tanks of 55,000 barrels each.

LABORATORY AT DESTREHAN, LOUISIANA.

New Orleans, Louisiana—The city of New Orleans is built on the Mississippi River, 110 miles from the Gulf of Mexico. New Orleans and New York are approximately the same distance from Chicago, and thirteen railroads connect New Orleans with all parts of the United States. Eighty steamship lines with agencies in the city operate from New Orleans to foreign ports in all parts of the world. 4,173 vessels with a total tonnage of 3,454,802 tons entered and cleared for foreign trade in 1920.

The port, as defined by Federal statute, has a front of 41.4 miles on both sides of the Mississippi River, seven miles of which are equipped with wharves, steel sheds, cotton warehouses, grain elevators, and other modern facilities. New Orleans is the port of the foreign trade of the Mississippi Valley, with Central and South America and the Far East, and much of that with Europe.

There are about 1,600 manufacturing plants in the city and the principal manufactures are boxes, burlap bags, cigars and

STATION AT SOUTHPORT, NEW ORLEANS.

tobacco, clothing, cotton, ice, lumber and sugar. The principal imports are coffee, bananas, sisal, nuts, oil, mahogany, sugar and molasses. In 1920 these imports amounted to $274,073,005, and the exports for the same period totalled $712,380,439.

The properties in Louisiana are owned by the Mexican Petroleum Corporation of Louisiana, Incorporated, which was formed on February 5, 1918, and include a refinery, storage stations at Southport, the City of New Orleans and Franklin. The refinery is situated at Destrehan, about 18 miles from New Orleans on land purchased in 1914, the area of which is 1050.5 acres. Seventy-nine tanks for the storage of crude oil, fuel oil,

gas oil, kerosene, crude naphtha, gasoline and asphalt, with a total capacity of 1,525,538 barrels, have been erected on the property.

Two storage stations have been built at New Orleans, one at Southport six miles from the city, and a second in the city on Galvez Street and New Basin Canal.

The station at Southport is on the left bank of the Mississippi River where tankers deliver oil at the Company's wharf and

STATION AT GALVEZ STREET, NEW ORLEANS.

where steamships, tugs and barges receive bunkers. There is a loading rack at the plant at which 20 tank cars can be filled simultaneously. The land, which was obtained in 1919, is ten acres in extent and on it have been erected two tanks of 55,000 barrels each.

The station in the city of New Orleans supplies gasoline, kerosene and fuel oil. The land on which the station has been built was acquired in 1917 and covers 3.17 acres. There are three sub-surface oil tanks, one for gasoline which has a capacity of 16,000 gallons, the second for kerosene of 17,000 gallons and the third for fuel oil of 10,000 barrels. These

products are delivered in the city by trucks and tank wagons; barges and tugs receive bunkers at the wharf.

Franklin, Louisiana—Franklin is situated in St. Mary's Parish on the Bayou Teche, in the center of the sugar cane belt, and is 101 miles by rail from New Orleans. The Franklin & Abbeyville Railroad, the Southern Pacific Railroad and the Morgan, Louisiana & Texas Railroad pass through Franklin. There are over 120 sugar plantations in the neighborhood, where sugar cane is converted into raw and refined sugar. During 1920

STATION AT FRANKLIN, LOUISIANA.

the Parish of St. Mary's produced 58,231,000 lbs. of sugar, 1,719,000 gals. of molasses, and 8,800 gals. of syrup. In addition there are several mills engaged in sawing timber. The cypress tree grows in great abundance on the swampy lands bounding the bayous. Factories for making paper, milling rice, and manufacturing oyster-shell products are in the vicinity.

The station of the Mexican Petroleum Corporation of Louisiana is built on the outskirts of Franklin, on a plot of land purchased in 1919, consisting of 5.76 acres, with a frontage on the Bayou Teche. A bulkhead 400 feet long has been constructed on the Bayou, where stern wheel boats burning oil

are bunkered, and where oil is delivered to barges. The station is equipped with one 55,000 barrel fuel oil tank, one 25,000 gallon gasoline tank, and one 25,000 gallon kerosene tank. The gasoline and kerosene are delivered in drums and tank wagons, and the fuel oil is distributed by barge, tank cars and motor trucks.

Galveston, Texas—Galveston is the most important port in Texas. Its imports for the fiscal year ending June 30, 1921, were valued at $26,666,409, the chief items of which were sugar,

STATION AT GALVESTON, EAST END, TEXAS.

bananas, coffee, oil, sisal and silks. The export trade has more than doubled during the past ten years and during the fiscal year 1920-1921 reached $550,033,922. It is the third largest of the cities in the United States from the point of view of export.

Galveston is noteworthy for its enormous trade in cotton and wheat. The total amount of cotton exported during the year ending June 30, 1921 amounted to 3,020,560 bales, and the wheat exports totalled 86,822,162 bushels. The industries in and around Galveston take large supplies of oil. The Mexican Petroleum Corporation purchased land at Galveston in 1919 and has two storage stations, one at the West end on a section of land of 6.41 acres on which have been built three tanks of 55,000 barrels each; and one at the East end on a portion of land of 38.479 acres on which six tanks have been built of 55,000 barrels

each. The total tank storage in Galveston is 495,000 barrels. There is a large extent of territory near the city of Galveston where fuel oil is used, and for the purpose of supplying customers, the Corporation operates several hundred tank cars. The oil delivered from the Galveston stations during 1921 amounted to 3,200,128 barrels.

LOCK IN PANAMA CANAL.

STATION AT CRISTOBAL, CANAL ZONE

The Panama Canal was opened for traffic on August 15, 1914. The obvious advantages of a canal across the isthmus at Panama attracted the attention of leaders in commerce for generations. Many futile attempts were made before its successful construction by American engineers. The Canal is one of the world's greatest engineering feats. To one who passes through the locks at Gatun, Pedro Miguel and Miraflores, there is nothing more impressive than the machine-like methods by which the largest

ships are passed from one lock to another. The order, cleanliness and neatness of every section of the Canal from Balboa to Cristobal represent the final word in efficiency.

The Canal is 42 miles in length between shore lines, and 50 miles long from deep water in one ocean to deep water in the other. The mean level of the Pacific is about eight inches higher than the mean level of the Atlantic, and the Canal is capable of handling about 48 ships of usual size in a day. The total

STATION AT CRISTOBAL, CANAL ZONE.

number of vessels passing through the Canal during November, 1921, was 222, with a registered gross tonnage of 1,184,157. The oil plants operated by oil companies, as well as by the Canal, have storage for approximately 1,250,000 barrels.

In 1915 the Mexican Petroleum Corporation obtained land at Mount Hope, Cristobal, for building tanks to supply oil-burning ships passing through the Canal. The area of the land is 6.2 acres, on which three tanks with a total capacity of 165,000 barrels have been erected.

STATIONS IN SOUTH AMERICA

Pará, Brazil—The Company owns through two subsidiaries, the Caloric Company and the Mexican Petroleum Corporation, seven stations on the eastern seaboard of South America, at points where there is the largest traffic both inland and seaward, and the most important industrial activities. Five of these are in Brazil, which has an area of 3,270,000 square miles. Brazil is the largest country in South America.

The city of Pará, officially called Belem, is the capital of the third largest state in Brazil, with an area of 443,992 square miles, and is situated in the centre of the torrid zone. Although near the equator, the climate of the city is relatively cool, on account of the trade-winds and the great rainfall. Owing to the moisture and heat there is immediately beyond the city a bewildering growth of trees, plants and parasites. Pará on the landward side is bounded by forests which prevent the development of suburbs, and threaten encroachments on the city itself.

Pará is built on a point of land formed by the entrance of the Guamá River into the Pará River, which itself is the estuary mouth of the Tocantins, incorrectly regarded as a tributary of the Amazon. The city is 86 miles from the Atlantic, and is the entrepôt for the Amazon valley. It is the headquarters of the Amazon Navigation Company, which has a large fleet of river steamers plying between Pará and the Peruvian frontier, and up all the large tributaries where there are trading stations. The port is accessible to ocean-going steamers, and boats of some of the largest lines in Europe and North America call at Pará.

The chief exports through Pará are rubber, cocoa, Brazil nuts, fibre, beans, and some of the best timber in the world. The imports of Pará for 1920 amounted to £2,250,000, equivalent to $10,935,000 at the normal rate of exchange, and the exports during the same year totalled £3,000,000 or $14,580,000. The main source of wealth is rubber, which grows in the sweltering forests that wall in the upper reaches of the Amazon and some of its tributaries. Many of the affluents of the Amazon are born amid

the snows of the Andes, and reach the more level regions by stupendous cataracts, whence they flow to the sea through those silent gloomy forests where the Pará rubber grows, which commands the highest price in international markets. Despite the competition in the East, and the superior methods of collecting

ROYAL PALMS, PERNAMBUCO.

and treating the latex, the quality of the rubber of the Amazon excels that grown in any other part of the world.

The increasing use of fuel oil in ocean-going steamers, the great trade in rubber, and the prospective development of timber and agriculture make Pará an important port for fuel oil station.

The Pan American Petroleum & Transport Company operates

in Brazil through the Caloric Company, which was acquired on March 21, 1916. At Pará, the Caloric Company has storage for 55,000 barrels of oil.

Pernambuco, Brazil—The state of Pernambuco is chiefly agricultural, the lowlands producing sugar and fruit; in the more elevated part of the State, cotton, tobacco, corn and beans

SCENE ON BRAZILIAN RIVER.

are grown. Cocoanuts, cocoa, bananas, mangoes and other tropical fruits are produced in abundance. The chief industry of Pernambuco is refining sugar and in the State there are more than a thousand refineries.

The capital is officially known as Recife, but is usually called Pernambuco, and it has the advantage over all other ports in Brazil of being the nearest to Europe. The harbor is not naturally protected like Rio de Janeiro, but two breakwaters have been constructed which give adequate protection to shipping. At

present a channel is being dredged to a depth of 33 feet, and when this is completed ocean-going steamers will find here safe anchorage.

The chief exports are sugar, cotton, goat skins, hides, rubber, flour and cocoa. The export trade in 1920 was almost £6,000,000, or $29,160,000, and the imports amounted to £8,250,000, or $40,095,000.

STATION AT PERNAMBUCO.

The Caloric Company has built two oil tanks at Pernambuco with a total capacity of 65,000 barrels. The land upon which the tanks are built has an area of 1.59 acres. The property is 130 meters from the quay, and a pipe line runs from the tanks to the quay. The proximity of Pernambuco to Europe, the demand for the produce of the country, and the progressive character of the State, justify the expectation of a largely increased business.

Bahia, Brazil—The eastern seaboard of South America, unlike the western, has many excellent harbors, and one of the best and most accessible of these is Bahia, built on a noble inlet studded with islands, and called Bahia de Todos os Santos. It is almost completely landlocked, and affords adequate shelter and accommodation for ocean-going steamers.

The commercial part of the city occupies a long narrow strip of land between the water line and the bluffs which rise almost

STATION AT BAHIA.

perpendicularly to a height of over two hundred feet above the sea level, affording splendid views of the bay and its islands.

Bahia is celebrated chiefly for its cocoa and tobacco. Other products of the state are sugar, cotton, hides, feathers, fibre, coffee, wax, mandioca and fruits; but the greatest industry of the state is the culture and preparation of cocoa, which is native to the Americas. The soil and climate combine to make the tree very fruitful. The groves run inland for two hundred miles along the valleys. "During the harvesting season a cocoa plantation presents a very pleasant sight, when the branches and even the trunks of the trees are thickly clustered with large red or yellow pods, somewhat resembling elongated melons." Bahia

a few years ago shipped 750,000 sacks of cocoa for which there is always a ready market.

In no part of South America is there a better grade of tobacco than Bahia, and its use dates before the landing of Columbus. The great manufacturing district is San Felix, across the bay from the city. Tobacco forms about 30% of Bahia's exports.

Brazil is so rich in its varieties of fruits, that many of the

ENTRANCE TO HARBOR, RIO DE JANEIRO.

most luscious specimens are unknown even by name beyond the borders of the country; and Bahia has the honor of being the home of the seedless orange. Here the owners of the trees need never worry over the necessity of smudges, since frost in this tropical district is unknown.

The exports during 1920 amounted to £8,750,000 or $42,525,000, and the imports totalled £5,000,000, or $24,300,000.

Bahia has a large coastwise and foreign trade, and is used as a port of call by many of the steamship lines trading between Europe and South America.

The property of the Caloric Company at Bahia covers an area of .62 of an acre on which has been erected one 55,000-barrel tank. The distance from the property to the quay is 130 meters, and an eight-inch line leading from the tank to the quay is provided with four connections for steamers or barges.

Rio de Janeiro, Brazil—Rio de Janeiro with its fairy-like settings girt about with mountains and its curving shore line laved by the waters of the blue Atlantic is unquestionably the finest harbor in the western hemisphere, and is universally regarded as one of the best in the world. The bay on which the city is built is 100 miles in circumference, and is surrounded by granite mountains, some of which rise stark and gray from amidst tropical glossy green foliage in impressive lonely isolation. The entrance to the bay is about a mile wide, guarded on

LOTUS PLANT, BOTANICAL GARDEN, RIO DE JANEIRO.

the southern side by the Sugar Loaf, a huge cone-shaped rock, bare of vegetation, at the base of which on the landward side lies the city of Rio de Janeiro. Within this beautiful bay, which is dotted with numerous islands, there is accommodation and shelter for fleet upon fleet of the largest ocean-going steamers.

STATION AT RIO DE JANEIRO.

The quays are fitted with the most modern equipment for loading and discharging cargo, and the docks extend for nearly two miles. The minimum depth of the water at the docks is 30 feet.

There is no other city on the coast of Brazil, and few in the world, with more attractive surroundings. Beyond the limited area of the city rise almost sheer a background of mountains covered with the densest vegetation. Wherever a ray of sunlight pierces, there is growth, and everything is on the gigantic scale of the tropics. There are ferns six feet tall; and, towering in

solitary grandeur above all other trees are the graceful royal palms. Many trees in this bewildering wealth of growth accommodate parasites with a foliage far in excess of their own, and the luxuriance of vegetation within and around the city is typical of the growth beyond the mountains. From the city radiate railways to bring the produce of the surrounding country to the port.

All foreign ships for South America call at Rio de Janeiro, and the import and export business there is very large. In 1920

DISTRIBUTING STATION FROM HARBOR, RIO DE JANEIRO.

the imports totalled £57,250,000 or $278,235,000, and the exports £15,750,000 or $76,545,000. Owing to the bunkering of numerous ships and the number of industrial plants in and around Rio de Janeiro, the Caloric Company has erected a large plant on the Saude Hill. The area of the property is 4.99 acres on which, in addition to boiler and pump house, there are four tanks, one of 10,000 barrels, two of 37,500 barrels each and one of 55,000 barrels. Besides this equipment, the Company has two barges, the *Sabrina* and *Caloric,* and five tank cars two of twenty and three of thirty-five tons. There are three twenty-ton tanks mounted on Leopoldina Railway trucks. For the delivery of oil

within the city and beyond several trucks are operated by the Company. The property is situated near the centre of the docks and the tanks are about 230 meters from the quay.

Santos, Brazil—Santos covers an alluvial plain on the inner side of an island called São Vicente, formed by an inland tidal channel sometimes called the Santos River. The river is deep and free from obstacles. In front of the city it widens to form

TANK CAR ON RAILWAY BETWEEN SANTOS AND SÃO PAULO.

a bay deep enough for the largest steamers. Santos was formerly, on account of the background of mangrove swamps, a nidus of yellow fever, but now it is one of the healthiest places in Brazil, and these former swamp lands produce beans, maize, mandioca and sugar. The quay of Santos is lined with warehouses and provided with railway tracks which connect the city with the coffee country in São Paulo.

The export trade from the port of Santos is the largest in

Brazil, and this depends mainly on the coffee grown on the rich hinterland. In 1920 the exports amounted to £53,250,000 or $258,795,000, and the imports to £37,000,000, or $179,820,000. It is perhaps on the great coffee *fazendas* that one gets the clearest idea of the wealth of the soil of this country, where the most modern methods are applied in the cultivation of this valuable

COFFEE PLANTATION, MONTEIROS, SÃO PAULO.

crop. There is nothing haphazard about the coffee industry, from the preparation of the soil to the shipment of the beans. Some of these fazendas are very extensive. On one, it is said, there are 13 million coffee trees. A plantation seen from the residence of the owner is a beautiful and impressive sight. The soil, which is kept free from weeds, is of a deep red color, and is in sharp contrast to the emerald glossy leaves of the coffee plant. One looks out upon a vast expanse of undulating

ground, covered with dark green shrubs planted in even rows, and stretching away to the horizon in unbroken symmetry. Each fazenda has a large drying-ground of concrete, where the coffee is laid in the sun. The beans are transported to the warehouses on the dock front at Santos from the nearest railway station, and shipped to every part of the world.

The State of São Paulo, which is the most progressive in

S. S. "S. M. SPALDING" DISCHARGING AT SANTOS, BRAZIL.

Brazil, is not entirely dependent upon coffee for its wealth. Sugar, rice, mandioca, cotton and maize are also grown; and during the last decade there has developed a very large trade in stock-raising. In the southern part of Brazil there are said to be more cattle than in Buenos Aires, which is the premier cattle province of Argentina. Industrial plants have sprung up since the War near the city of São Paulo, and the largest plant in Brazil recently completed is owned by a Chicago company.

The distance between São Paulo and Santos is about fifty miles, but the steep wooded slopes of the Serra do Mar lie between the two cities; and one of the best built and most carefully maintained railways in the world connects the docks with the capital of São Paulo. It is a triumph of engineering, rising 2,500 feet in a distance of over six miles; and this short line is the channel by which the bulk of the world's coffee is carried.

The port facilities at Santos and the oil tanks are controlled by a company under contract with the Government; one of these tanks, which has a capacity of 55,000 barrels, is used by the Caloric Company. In addition to this tank, the Caloric Company owns ten tank cars, each having a capacity of 35 tons, which are used to carry the oil beyond the city.

Montevideo, Uruguay—Uruguay, locally called the Banda Oriental, meaning the land on the eastern side of the River Uruguay, although the smallest independent state in South America, is a rich agricultural land, and enjoys the reputation of possessing one of the healthiest climates in the world. Cattle breeding and sheep farming is carried on in all parts of the Republic, and its Paysandu ox tongues and beef extract from the Liebig factory are known throughout the world. There are no high mountains, and the land consists mainly of undulating plains. The pastoral wealth of Uruguay and Argentina is due to the fertilizing constituents of "pampa mud."

The foreign trade of the country passes through Montevideo, on the Rio de la Plata. There are many miles of railway in Uruguay, and a trunk line connects the port of Montevideo with Rio de Janeiro. The harbor of Montevideo forms a half circle, and is two and a half miles from point to point. It is well protected by breakwaters, and is dredged to a depth of 27 feet. The rise and fall of the water is due mainly to winds; a south wind means high water, and a north wind low water.

The property of the Mexican Petroleum Corporation, which is the subsidiary under which the Pan American Petroleum &

Transport Company operates in Uruguay and Argentina, is situated at Bella Vista. The area of the land is .91 of an acre on which one 55,000 barrel tank has been erected; a ten-inch pipe line connects the tank with the pump house and dock. Montevideo is a progressive city, and the traffic from the interior by rail is increasing. Some of the stationary plants have installed fuel oil; and its importance as a port of call for European and North American steamers is steadily growing.

STATION AT MONTEVIDEO.

Buenos Aires, Argentina—The commercial and political status of Argentina has risen during the past thirty years with a rapidity that has few parallels. The normal progress of a century was compressed into a few decades.

The area of the country is over a million square miles. In Argentina there are great extremes of temperature, from the land which borders on Bolivia within the tropics, with its forests of palms, to the territory of Tierra del Fuego, where snow falls during every month of the year. The western boundary of Argentina is formed by the Andes, where are some of the loftiest mountains in the world, and which in the northwest extend far into the country. Outside the extremes of temperature

and the ranges of snow-clad mountains, there is a relatively flat plain known as the "pampas," of vast acreage, and on which the wealth of Argentina depends. Pampa is the South American Indian name for level spaces, and these pampas seem almost as flat as a billiard table, though the slope of the land from Buenos Aires to Mendoza averages about three feet per mile. Over these pampas roam huge herds of magnificent cattle, and from the rich soil of these plains spring crops of grain that are not excelled in any other part of the world. The climate of the pampas is temperate and healthful, and admirably suited to agricultural and pastoral pursuits.

Thirty years ago South American countries were looked upon as lands of revolution and fever. Today the government of Argentina is stable, and the streets of Buenos Aires are as well paved and lighted, and the city is as sanitary as any in Europe or the United States. Calle Florida, in its window displays, vies with Fifth Avenue or Bond Street. The parks of the city are spacious and decorative, and its main public buildings worthy of any metropolis. A few years ago Buenos Aires was a mere village, with only the most primitive methods of transportation. Many residents of the city who came from Europe were conveyed on bullock wagons from the steamer through the river to the town. Today Buenos Aires is the largest city in South America, and despite its great natural disadvantages, a magnificent harbor has been constructed at great expense, with every modern dock equipment, and adequate for the vast export business which is carried by some of the largest and most modern ships afloat. Each railway of the country has a terminus in Buenos Aires, and one of these railways connects Buenos Aires with Valparaiso on the Pacific. New lines are being extended towards the promising districts among the Andean foothills. With the exception of about 130 miles, Buenos Aires is connected by rail with La Paz, the capital of Bolivia.

The Mexican Petroleum Corporation owns property outside the limits of the city of Buenos Aires, in a district known

as Dock Sud. The area of this property, which was acquired in 1919 and 1921, is 7.94 acres. Three tanks of 55,000 barrels each and a pump and boiler house have been erected, and preparations have been made for the building of an additional tank. One ten-inch pipe line from the waterfront is connected into the manifold 672 metres distant, so that the Company's tankers can pump direct into the tanks. There is no country in South America where the need of fuel oil is greater and its value more

STATION AT BUENOS AIRES.

clearly recognized than in Argentina. The future of the country is assured because of its great natural wealth and the progressive character of its people.

STATIONS IN GREAT BRITAIN

The British Mexican Petroleum Company, Ltd., incorporated on July 15, 1919, was formed mainly for the purpose of supplying the transatlantic trade with marine fuel. The rapid conversion of so many of the largest passenger steamers, and the construction of others which will run on fuel oil, necessitate adequate and convenient supplies, not only in the United States, but also at the main ports of the United Kingdom.

Great Britain has converted some of her largest ships to fuel oil, and her imports of various oils from 1913 to 1921 have shown a striking increase. The total amount of fuel oil imported during the first nine months of 1913 was 62,349,306 gallons; during the first nine months of 1921 the imports reached 415,141,311 gallons.

A large proportion of the Atlantic trade is between the United

BUNKERING THE S. S. "AQUITANIA" FROM BARGE OF BRITISH MEXICAN PETROLEUM COMPANY, LIMITED.

States and Great Britain; and the British Mexican Petroleum Company has stations at Southampton, Liverpool, Avonmouth, South Shields, Glasgow and facilities for handling oil at Thames Haven.

Southampton—The present prosperity of Southampton dates from the opening of railway communication with London in 1840, and the harbor is one of the best in the United Kingdom. It has the advantage of a double tide, the tide of the English Channel giving it high water first by way of the Solent, and two hours later by way of Spithead. The docks cover an area of many hundred acres, comprising extensive quays in both the

Test and Itchen Rivers. The water is of sufficient depth to accommodate the largest ocean-going steamers. The total net tonnage of ships that cleared from Southampton during 1921 was 5,392,940. The property of the British Mexican Petroleum Company lies at the mouth of the River Itchen, where it enters the Southampton waters. It consists of a plot of land seven

STATION AT SOUTHAMPTON.

acres in extent, and on this have been erected four tanks of 8,000 tons each, and one of 3,500 tons. There are two 10-inch lines from the tanks to the dock, whence the oil is conveyed by barges to ocean-going steamers. The equipment for this purpose consists of one self-propelled barge, *Inveritchen,* with a capacity of 1,200 tons, and five smaller barges of 800 tons each. The *Olympic, Aquitania* and other large vessels take oil from the Southampton station of the British Mexican Petroleum Company,

Liverpool—The city of Liverpool is situated on the right bank of the estuary of the Mersey, and the center of the city is about three miles from the open sea. The export trade from Liverpool is the largest in the United Kingdom. It lies near the great manufacturing districts of Lancashire and the West Riding of Yorkshire, and is the natural channel of transmission for their goods. The total net tonnage of ships that cleared from Liverpool during 1921 was 12,354,794.

STATION AT LIVERPOOL.

The property of the British Mexican Petroleum Company is on the southeastern boundary of the Dingle Bank Estate, which has been set aside by the Mersey Dock & Harbor Board for the purpose of bulk storage oil. The land covers an area of 7.75 acres, and its southeastern boundary is formed by the bank of the River Mersey. The Mersey Dock & Harbor Board have plans for the construction of a new oil dock on the river, directly in front of the Dingle Bank property. The British Mexican Petroleum Company has erected three tanks each with a capacity of 8,000 tons, and one of 3,500 tons. Two ten-inch lines run from the tanks to the dock, and two barges each of 800 tons are in use at Liverpool.

Avonmouth—The commercial history of Avonmouth and Bristol are closely linked together. In 1884 the Avonmouth and Portishead docks at the main entrance were bought by the city, and the port extends from Hanam to the mouth of the river and for some distance above the estuary of the Severn. The city docks have a depth of 22 feet, while those of Avonmouth are accessible to the largest vessels. In 1908 the Royal Edward Dock at Avonmouth was opened. It is entered by a

STATION AT AVONMOUTH.

lock 875 feet long and 100 feet wide, with a depth of water on the sill of 46 feet at ordinary spring, and 36 feet at ordinary neap tides. The port has a large trade with America and the West Indies. The principal imports are grain, fruit, oil, ore, timber, hides, cattle and general merchandise, and the exports include machinery, cotton goods, tin and salt. The Elder Dempster, Dominion and other large steamship companies trade at the port.

The station of the British Mexican Petroleum Company is situated at the junction of the Rivers Avon and Severn. In the part of Avonmouth known as the Port of Bristol, the Port of Bristol Dock Board is constructing an oil dock for the use of

oil companies, and the entrance to this is through the Royal Edward Dock, where a depth of water of 36 feet is maintained. The area of the Company's property is five acres, upon which have been built, in addition to the pump house and offices, two 8,000 ton tanks. There are two 10-inch lines from the tanks to the dock.

South Shields—South Shields is about eleven miles from Newcastle-upon-Tyne, and the banks of the river below the city are lined with docks and industrial towns. The district owes its

STATION AT SOUTH SHIELDS.

immense prosperity to the mineral wealth of the neighborhood. The chief exports are coal, chemicals, pig iron, ironwork, steel, iron bars, plates and castings, machinery, fire-clay and copper; and the chief imports are fruit, wheat, maize, oats, barley, iron, and steel, petroleum, sulphur ore, timber and wood hoops, iron ore and potatoes. Steamers carrying passengers serve the principal English ports, also the Baltic ports and New York. In addition to the industries of Newcastle, may be added the most important of all, namely, shipbuilding. The celebrated Elswick Works, which are situated in the western part of the Borough of Newcastle, construct ships of all kinds, including the largest iron-clads with all their armor and guns. Vessels of

large tonnage can ascend the river as far as Newcastle, but the berths of the ocean steamers are a little further down the river.

The station of the British Mexican Petroleum Company is near the open sea, and has an area of 1.9 acres. There are five tanks on the property with a total capacity of 16,000 tons, and a 6-inch pipe line connects the tanks with the dock. A self-propelled barge, the *Invertyne,* is in use at South Shields.

BIRD'S EYE VIEW OF STATION AT GLASGOW.

Glasgow—Glasgow, the largest city in Scotland, and one of the principal ports of Great Britain, is built on the River Clyde. The total net tonnage of vessels leaving the port during 1921 was 4,456,656. The imports consist chiefly of flour, fruit, timber, iron ore, live stock, and wheat; and the exports principally of cotton manufactures, manufactured iron and steel, machinery, cotton yarn, linen fabrics, coal, jute, jam and foods, and woolen manufactures. Shipbuilding is the greatest of the

industries of Glasgow, and in some years more than half of the total tonnage in the United Kingdom has been launched on the Clyde, the yards of which extend from the harbor to Dumbarton on one side and Greenock on the other side of the river and firth. The British Mexican Petroleum Company, Limited, has a large station at Bowling, fourteen miles below Glasgow, near Dunglass Castle. The property is 64 acres in

NEARER VIEW OF GLASGOW STATION.

extent. A dock was dredged into the property of sufficient depth to accommodate tankers. It is surrounded on three sides by a levee, and is dredged to 27 feet at low water, for an area of 200 by 600 feet. From the levee, piers are built out to deep water in the dock. Two tanks of 8,000 tons each and one of 3,500 tons have been built on the property, and two 10-inch pipe lines run from the tanks to the east side of the dock. There is one self-propelled barge, the *Inverampton,* with a capacity of 8,000 barrels, attached to the station, which is similar to the *Inveritchen* at Southampton.

CHAPTER VII

REFINING AT TAMPICO AND DESTREHAN

THE METHOD of treating crude oil and crude naphtha at Tampico and Destrehan, with a short account of the main physical features of the two refineries are given in this chapter.

In its crude state petroleum can be used only as fuel, and then with few exceptions it is dangerous because of its gasoline content; the vapors of gasoline accumulate in the storage tanks or around leaky connections and may cause explosions and resulting fires.

When petroleum is refined, not only valuable products like gasoline and kerosene are extracted, but at the same time it yields a refined fuel which can be handled with perfect safety; the more complete the refining process, the more numerous the products which can be separated from the crude oil.

A visit to a petroleum refinery is usually disappointing to the layman. All he sees are tanks, pipe lines, and the outside brickwork of the stills. There is no excitement awaiting him, and no sound save the hum of motors and the rhythmic movement of pumps. Everything seems to go on automatically, and this is so because a modern petroleum refinery is a plant where man is master and not a slave of machinery. It is similar to a modern power plant where one sees only the big turbines, dynamos and switchboard and a few men walking quietly around, watching the gauges, touching a switch here and there, or adjusting a valve.

Refining—The first step in the refining of petroleum is

distillation. The crude oil as it comes from the well is a mixture of various hydrocarbons, i. e., chemical compounds of carbon and hydrogen. There are also present small amounts of other chemical compounds containing nitrogen, oxygen and sulphur, but the hydrocarbons are the chief and most important group. The lighter hydrocarbons, that is those containing fewer atoms of carbon and hydrogen to the molecule, have a

REFINERY AT DESTREHAN, LOUISIANA.

lower specific gravity and a lower boiling point than hydrocarbons of a similar chemical composition, but whose molecules contain a greater number of atoms. If a mixture of hydrocarbons be heated in a suitable vessel, the lighter compounds begin to evaporate and volatilize while the heavier hydrocarbons remain as a liquid, due to their different boiling points; and the possibility of separating the lighter hydrocarbons—fractions—from the heavier ones according to their different

boiling points is the fundamental principle of the technology of petroleum refining.

For the manufacture of fuel the crude is topped, i. e., only the light fractions (crude naphtha) are distilled off, leaving as residue an oil which is heavier than the original crude oil, but which can be handled with perfect safety, because it has a high flash test and will not give off explosive vapors, even when heated almost to the temperature of boiling water. An-

TUBULAR CRUDE STILLS.

other advantage of using topped fuel oil instead of crude oil is that a given volume of the heavier oil when burned will produce more heat than an equal volume of the original crude oil; the calorific value of a gallon of fuel oil is greater than that of a gallon of crude oil.

The topping of crude oil is usually performed in special pipe stills. A pipe still is simply a series of pipe-coils built in a furnace. Crude oil is pumped through these coils and heated to a predetermined temperature, then it flows into an evapor-

ator, i. e., a tank where the vapors of fractions which evaporate at that temperature can separate from the body of oil. The vapors then pass through a condenser, and form the distillate or "crude naphtha," while the residue (the fuel oil) runs from the evaporator, through a cooler, into a storage tank. This operation is a continuous one, and has the advantage of simplicity of apparatus and economy in the consumption of fuel.

The distillate which is obtained by topping crude oil is a mixture of gasoline and kerosene; the lighter gasoline is separated from the heavier kerosene again by distillation. This is done in so-called "steam stills," where the gasoline is distilled over usually by means of steam only. Gasoline is obtained as distillate, while kerosene remains in the still as residue.

If the crude oil is distilled in cylindrical stills, then "crude naphtha" is obtained as the first fraction, and next comes the kerosene distillate. The gasoline is usually redistilled in steam stills in order to separate from it the last traces of the heavier fractions so as to obtain a uniform product. Good gasoline must distill over below a specified boiling point and when poured on a sheet of white paper it should not leave on evaporation a greasy spot or ring.

A typical oil still is a horizontal cylindrical steel boiler or evaporator suspended on lugs over a brick furnace. This furnace is built so that the side walls reach over the sides of the boiler and cover it, and only the lower part of the still is exposed to the heat. The stills are usually fired by fuel oil. The vapors pass from the still through a vapor-line to the condenser; the condenser consists of a coil or a series of coils of pipe built inside a tank. The vapors pass inside the coil which is cooled by water on the outside; cold water is fed into the bottom of the condenser tank, and after absorbing the heat from the vapors, it overflows into a drain. The vapors condense in the coil to a liquid, which runs out of the "tail pipe" into a manifold. By means of the manifold and its connections, the distillate can be run according to its gravity into the proper tank.

At first crude naphtha will distill over as the lightest fraction; next comes kerosene distillate; then gas oil; and afterwards the heavy paraffin distillates. These are all crude distillates, and require further processing before finished products are obtained, with the possible exception of gas oil, which is usually marketed as initially produced. The others, such as crude naphtha, upon proper treating and steam stilling, yield gasoline; kerosene distillate upon redistilling and treating, yields kerosene; and paraffin distillate upon redistilling,

GASOLINE STEAM STILLS.

wax elimination, treating, reducing and filtering, yields lubricating oils. If the still be heated until no more oil distills out of it, there will remain in the still a layer of dry porous coke, as the ultimate residue. In actual refinery practice only a portion of the crude is distilled to coke; a great deal is only partly distilled in order to obtain fuel oil or asphalt of various grades as the residue.

As mentioned above, kerosene can be improved by redistilling, for even after distillation gasoline and kerosene oils are not suitable for use without further treatment; they still con-

tain impurities which impart to them an unpleasant odor, and which would cause darkening of the distillate if stored for any length of time. The kerosene especially is liable to burn in lamps with a smoky flame and to char the wick. In short, the distillate is not yet a marketable product.

To remove these impurities, the distillates are treated with sulphuric acid. The action of the sulphuric acid is both a chemical and a physical one and forms insoluble chemical compounds

REFINED OIL AGITATORS.

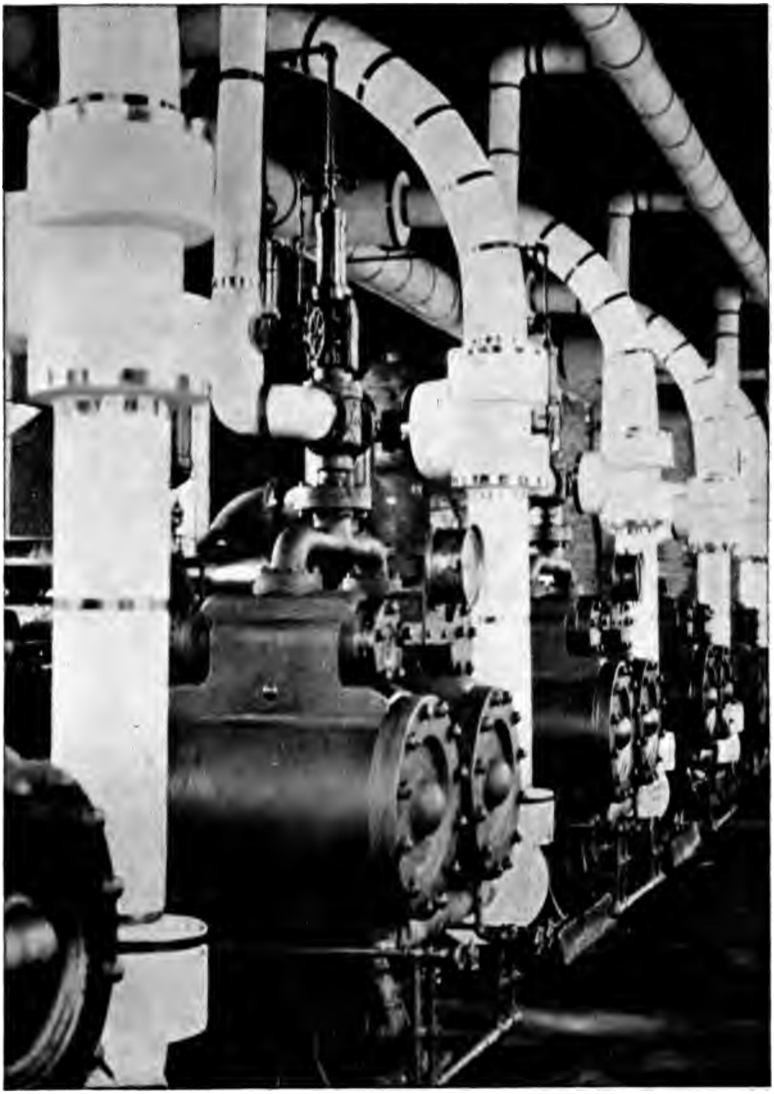
with the impurities and also acts as a solvent for them and the newly formed compounds, while pure kerosene or gasoline is not acted upon by the acid.

In refining practice, the treating is done on a large scale, one thousand barrels or more at a time, in agitators, i. e., big cylindrical iron tanks with cone-shaped bottoms, usually lead-lined to protect the iron from corrosion by the sulphuric acid. The distillate, either kerosene or naphtha, is mixed with the acid and agitated by means of compressed air blown into the bottom

of the agitator or by any suitable mechanical contrivance. After the mixing has been completed, the acid sludge is allowed to settle and is then drawn off by a valve at the bottom of the agitator. The oil is afterwards washed with water and next with a solution of alkali to neutralize the acid which may still be retained by the oil, and is finally washed several times with water to remove the last traces of alkali. After this treatment with sulphuric acid and alkali, the gasoline or kerosene is water white and has only a faint, aromatic odor.

It is not generally understood by the layman that gasoline is not a single hydrocarbon, but a mixture of very many different hydrocarbons, some of similar and some of different boiling points; therefore, gasoline will not boil at a constant temperature, but within a long range of temperatures, e. g., a commercial gasoline which meets the Bureau of Mines specifications, will begin to boil at about 140° F. or lower, while the heaviest parts will boil at or below 437° F. The main point is that a good commercial gasoline should have a uniform range of boiling points from the lowest to the highest, *and this and not the gravity should be the criterion of quality.*

In the early days of the refining business, when illuminating oil was the chief commodity of the refinery, and brought a higher price than gasoline, the distilling operation was so regulated that the fractions, which now constitute the higher boiling fractions of gasoline, were included in the kerosene fraction. By this procedure, the production of kerosene was increased at the expense of gasoline. In those days gasoline had a gravity of from 66° to 72° Baumé, and was used mostly as a fuel for gasoline stoves, and no consideration was given to the range of boiling points as is now required for a good motor fuel. As the internal combustion engine becomes more highly perfected, it will be able to use lower grade gasoline, or gasoline with more of the kerosene fraction in it. This will enable the refiner to increase his production of gasoline from crude and assist in meeting the ever increasing demand for motor fuel. At



REFINED OIL PUMP HOUSE, DESTREHAN.

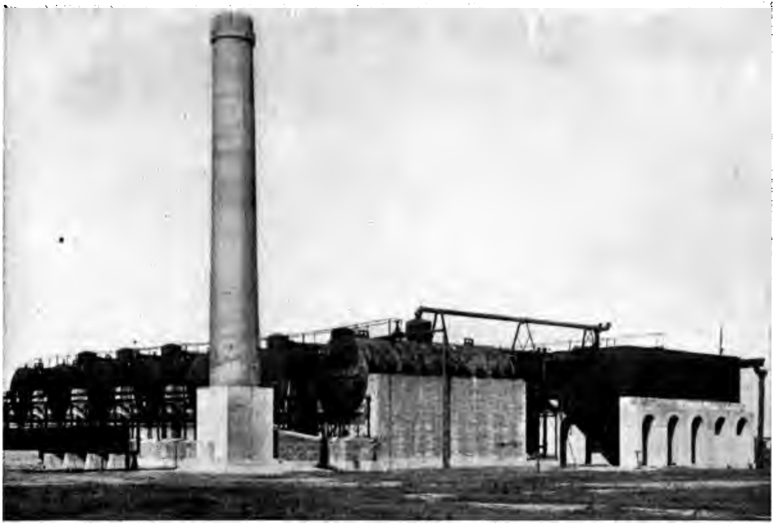
present the demand for gasoline is so great that it cannot be supplied by the production of natural gasoline from crude oil, and, as a result, the refiner has been compelled to find other ways to produce low boiling hydrocarbons suitable for internal combustion engines. This problem has been solved to a very great extent by the so-called "cracking process," whereby high boiling hydrocarbons are converted into low boiling hydrocarbons by destructive distillation, i. e., generally speaking by overheating the oil above its boiling point, either as a liquid under pressure or as a vapor, according to the method employed.

This overheating causes the molecules of the high boiling hydrocarbons to disintegrate and form new combinations of atoms, some forming gasoline fractions; others permanent gases as light as methane, or marsh gas, and also heavy residues and even coke are formed. By the highly perfected processes now employed, the refiner is able to obtain as much or more so-called "synthetic" or "cracked" gasoline from heavy oils or residues, as he was able to obtain natural gasoline from the original crude oil. Thus the refiner has been enabled to keep pace with the ever increasing demand for motor spirits without an undue increase of price which would be inevitable had the supply to rely exclusively on the production of natural gasoline.

Another very important product manufactured from Mexican crude oil is asphalt. Before artificial asphalt was introduced in the paving industry, only natural asphalt was used, as obtained from huge natural deposits, such as those found in Trinidad. Since artificial asphalt can be produced economically, of a quality equal or superior to the natural asphalt, it has been widely used in North America and Europe. Roads which were laid with Mexican asphalt years ago are still in good condition, which is the best proof of the high quality of this material. The artificial asphalt has also the advantage that it can be made in various grades of hardness and transported in a pure state, to be mixed with the other ingredients, to suit local conditions

and requirements. This advantage will be readily understood when it is realized that an asphalt pavement contains not over 12% of the asphaltic cement, the rest being mineral aggregate, and that an average refined Trinidad asphalt contains roughly one-third of its weight of mineral matter.

Asphalt is produced from an asphalt or semi-asphalt base crude oil as residuum, i. e., after all the lighter fractions have been dis-



BATTERY OF CONTINUOUS ASPHALT STILLS.

tilled off. This distillation is carried on in special stills, because the utmost care is necessary to obtain a product which shall correspond to various very strict specifications. To facilitate the distillation, live steam is introduced into the still through a perforated coil lying on the bottom of the still. The stills are equipped with thermometers and pyrometers, because the temperature must not exceed specified limits set for the different grades of asphalt. Samples are drawn from the stills at fre-

quent intervals to be tested in the laboratory for hardness or penetration, melting point, and many other rigid specifications.

The harder grades of asphalt are used mainly for paving and water-proofing; the softer grades and fluxes for impregnating felts, building papers, and for roofing purposes. A special asphalt of a very high melting point, which is at the same time very elastic, is made by oxidizing asphalt at a certain stage of the distillation by blowing air through the body of the asphalt. This grade is used as an elastic cement for roofing and various other special purposes where a high melting point elastic material is desired.

When Mexican oil is reduced to asphalt, a heavy distillate is produced after the lighter fractions are distilled off. This heavy distillate by proper manufacturing processes can be made into very high grade lubricating oils and waxes. This process in general consists of removing the paraffin wax to prevent the oil from solidifying at low temperatures. The wax-free oil is then concentrated to the proper viscosity, and finally is treated with sulphuric acid and washed with alkali, thereby removing the tarry and resinous bodies injurious to a lubricating oil. According to the grade and viscosity of the oil, its color will vary from pale yellow for the light oils, to dark red for the heavier grades or cylinder oils. For the finest grades and the higher priced oils, it may be further purified and improved in color by filtering through Fuller's earth.

The paraffin wax as removed from the raw lubricating oil is known as "slack wax," and contains, besides paraffin wax, oil and other impurities. It is converted into refined paraffin wax by first removing the last traces of oil in so-called "sweating ovens." Here the slack wax is placed in shallow trays with perforated bottoms, and as the temperature of the oven is gradually raised, the oil seeps out of the wax, which is called in the industry "sweating." After the sweating is completed, there remains in the trays a dry oil-free cake of wax now called "crude scale," which is then removed for further purification.

This consists in acid-treating and filtering through Fuller's earth or bone-black. The wax is then molded into cakes and becomes the well known refined paraffin wax of commerce.

Refinery at Tampico—This refinery is built in two sections and consists of eleven batteries each containing six tubular heaters. The capacity of each is above 2,000 barrels, and 135,000 barrels can be handled daily in the two units. In addi-

REFINERY AT TAMPICO, WITH OFFICES IN FOREGROUND.
(Plant No. 1)

tion there are three re-run heaters with a capacity of 5,000 barrels, making a total of 140,000 barrels.

As explained above when the crude oil which passes through the heaters reaches the proper temperature, it goes into evaporators where the vapors separate from the body of the oil. These vapors pass through the condensers to the receiving tanks in the form of crude naphtha, and the residue in the evaporators runs through a cooler into storage tanks. In the re-

run stills, the heavy crude naphtha is refractionated into a light fraction and a gas oil residue.

In order to provide gasoline, a steam still and an acid agitator for treating the crude naphtha have been erected. There are two pump houses for delivery of the crude oil to the heaters, for handling the distillate, the tower circulating oil, and the residue. There is also a gas absorbing plant to handle waste gases

REFINERY AT TAMPICO.
(Plant No. 2)

from the condensers in which a light gravity crude naphtha is extracted, the separated gas being used for fuel purposes.

The condensing water pumping plant has a capacity of ten million gallons, and consists of four electric driven centrifugal pumps, which take water from the Panuco River and force it to the refinery for use in the condensers.

Refinery at Destrehan—The Company has a refinery at Destrehan, located 18 miles from New Orleans, where the various

products described above are manufactured from oil shipped from Mexico. The refinery is built on the east bank of the Mississippi River, on a tract of land 1050.5 acres in extent. On the river a wharf 950 feet long has been constructed, capable of accommodating two tank steamers, either delivering oil from Mexico or loading gasoline or other refined products. There is over 30 feet of water at the dock, even with the river at its lowest stage, so that the largest tankers of the Company can be

SULPHURIC ACID RECOVERY PLANT.

docked at all times. The west approach to the dock carries the pipe lines to and from the refinery proper, and there are separate lines for handling gasoline, kerosene, gas oil, crude oil, fuel oil, and water.

The crude oil shipped from Mexico is run through cylinder and tubular stills with a combined capacity of 25,000 barrels daily, producing crude naphtha, kerosene distillate, gas oil, and various other products. The crude naphtha produced is treated in agitators, after which it is run through tower steam stills, to make finished gasoline. Recently there has been erected at

the refinery a plant for manufacturing synthetic gasoline. This is a gasoline, as previously mentioned, made from heavy oil which, prior to cracking, contained no gasoline. There are also agitators for acid treating kerosene distillate to make finished kerosene. The sludge acid from the treatment of crude naphtha and kerosene will be recovered in a new acid restoring plant in process of construction. This plant will be able to recover 60% of the original acid used and represents an economic feature not directly connected with the production of oil.

In addition to the manufacture of gasoline and kerosene, one of the chief industries of the refinery is the manufacture of asphalt, which is shipped by tank cars or in barrels. These barrels are made on the premises, either of wood or steel. As the traffic and climatic requirements of each country are different, asphalts are manufactured from the Mexican oils to comply with the most rigid specifications to meet any conditions.

Besides stills, agitators, tanks, etc., it is necessary to have auxiliary equipment such as boiler houses, pump houses, shops, power plant, barrel factory, railroad trackage, car loading facilities, store house, offices, laboratory, etc.; and, owing to the location of the plant, houses for the officers and employees. There are two main boiler houses containing 3,000 horse power boilers of the most modern type, equipped with a water purifying plant. There are three main pump houses for handling the various oil products, and one water pumping station for handling condensing water, boiler feed water and fire service. The power plant consists of two 750 horse power electric generators, for supplying power to motors, lights, welding, etc., and air compressors for the use of the shops and plant in general. The shops are well equipped with tools for making repairs or construction work. The laboratory is especially well supplied with apparatus for testing oils, and also for research work of the most advanced character.

Many of the five hundred employees live at the refinery, in neat, well-built houses, all completely screened and furnished

with hot and cold water and every modern convenience; and lands have been set aside for baseball, tennis and other outdoor sports. The Old Manor House, erected nearly two hundred years ago, which faces the river, is shaded with broad-armed live oaks, and makes a beautiful home for the general superintendent. There are two schools on the property. All milk used by the employees is supplied by a dairy owned by the Corporation, and a doctor resides at the refinery, where there has been erected a well-equipped modern hospital.

HOMES FOR EMPLOYEES AT DESTREHAN.

CHAPTER VIII.

ADVANTAGES OF FUEL OIL AND INSTALLATIONS FOR STATIONARY PLANTS

ADVANTAGES OF FUEL OIL

THE discovery of fire by man was his first great step in material development, the story of which is woven into the most impressive legends in literature. Prometheus, the inventor and teacher of the arts of life, is represented in his truly ''philanthropic fashion'' as stealing fire, much to the dismay and irritation of Zeus. Whatever facts correspond to the legends that are associated with man's first use of fire, there can be no doubt that wood was his first fuel, and by this means primitive man cooked his food and heated his rude dwelling.

The next great step was marked by the discovery of coal. Its application to heat and power have been mainly responsible for the advances that were made in the last century in commerce and industry. The perfecting of the methods of raising steam by coal went hand in hand with, and aided in, the development that marked that strikingly progressive era. The ends of the earth were reached by fast steamships, and new continents were opened up to commerce by railroads. Factories at convenient centres were built to manufacture raw materials transported by rail or steamship from the farthest corners of the globe.

Towards the close of the nineteenth century the world began to be awakened to the value of a new fuel—oil. A few saw its superiority and took advantage of it; but the Great War focussed the attention of the world upon oil; and today the pos-

with hot and cold water and every modern convenience; and lands have been set aside for baseball, tennis and other outdoor sports. The Old Manor House, erected nearly two hundred years ago, which faces the river, is shaded with broad-armed live oaks, and makes a beautiful home for the general superintendent. There are two schools on the property. All milk used by the employees is supplied by a dairy owned by the Corporation, and a doctor resides at the refinery, where there has been erected a well-equipped modern hospital.

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ADVANTAGES OF FUEL OIL

THE discovery of fire by man was his first great step in material development, the story of which is woven into the most impressive legends in literature. Prometheus, the inventor and teacher of the arts of life, is represented in his truly "philanthropic fashion" as stealing fire, much to the dismay and irritation of Zeus. Whatever facts correspond to the legends that are associated with man's first use of fire, there can be no doubt that wood was his first fuel, and by this means primitive man cooked his food and heated his rude dwelling.

The next great step was marked by the discovery of coal. Its application to heat and power have been mainly responsible for the advances that were made in the last century in commerce and industry. The perfecting of the methods of raising steam by coal went hand in hand with, and aided in, the development that marked that strikingly progressive era. The ends of the earth were reached by fast steamships, and new continents were opened up to commerce by railroads. Factories at convenient centres were built to manufacture raw materials transported by rail or steamship from the farthest corners of the globe.

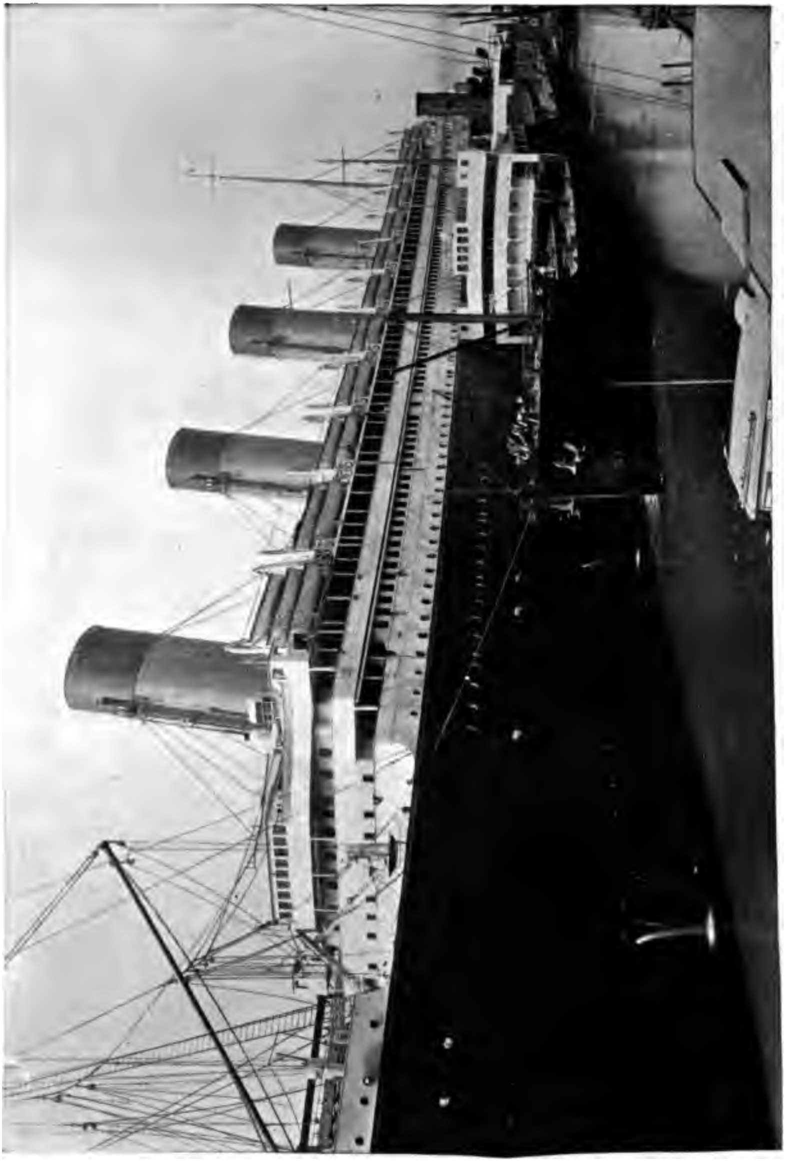
Towards the close of the nineteenth century the world began to be awakened to the value of a new fuel—oil. A few saw its superiority and took advantage of it; but the Great War focussed the attention of the world upon oil; and today the pos-

session of petroleum lands has become one of the most important of national and international questions.

It required an intensive and prolonged campaign by the Mexican Petroleum Corporation to induce one factory in New England to try fuel oil. Certain definite guarantees of saving that would be effected if oil were used in the boiler room were made, and after discouraging delays one factory tried it. The results were so far beyond what was expected, that immediately every barrel sold became a flaming advertisement. When the War broke out this Company had not a single truck or tank car in New England. Today there are 318 tank cars operating in Boston alone, twenty of which can be loaded in two and a half hours. As one drives from factory to factory through New England, numerous tank cars and trucks of the Mexican Petroleum Corporation meet the eye, making deliveries or returning to the storage stations for more fuel. The winter of 1919-20 was one of exceptional severity, which created great difficulties for the delivery of coal. There is not a single instance where any mill, factory or institution burning "Mexpet" fuel oil was short of fuel since deliveries were begun in 1915.

The Corporation supplies oil to large plants in the United States that are engaged in varied industries and activities such as cotton goods, woolens, automobile tire fabrics, shoes, phosphates, sugar, copper, rice, ice, steel, silver, dyes, bleaching, paper, rubber, and also to laundries, hotels, offices, department stores, nurseries, apartment houses, hospitals, clubs, colleges and churches. It is also sold to assist in dredging, and for use on railroads and in steamships. From all boiler rooms, whether on sea or land, comes the same story of entire satisfaction and numerous advantages in the use of fuel oil.

Since the Armistice, many of the largest passenger ships have been equipped for burning oil, and the reports that come from its use at sea not only emphasize the features that are most striking in stationary plants, but additional advantages are dwelt upon by engineers of shipping companies. Since the *S. S. "Olympic"* was converted to an oil burner, she has been run



BUNKERING S. S. "OLYMPIC" FROM S. S. "WILLIAM GREEN," NEW YORK, JULY, 1920.

solely on oil purchased from this Company; and a statement by the International Mercantile Marine Company on the superiority of oil is of great interest. The *Olympic* is of 46,439 tons register, and about 60,000 tons deadweight, and her engines register 50,000 horsepower. Her owners say:—

"The stokers, or 'black squad', and the grime and heat disappeared on the *Olympic* when the oil fuel came into use. Even well established terms disappeared at the same time, for the former stoker is now known as a fireroom attendant.

"With coal as fuel, this huge vessel carried no less than 246 firemen, who were shoveling with high-wrought energy, by turns day and night incessantly, in heat and coal dust to feed her fires. In hot weather conditions, her firerooms were almost intolerable, and not a day passed that did not see from twelve to fifteen men pass under the ship's doctor, suffering from heat exhaustion, burns, bruises or physical breakdown, incurred in the furious labor of feeding those insatiable, glowing, roaring furnaces.

"With the installation of oil fuel all that changed as if by magic. In place of 246 men, comprising the 'black squad', only 60 are now required to attend the oil burners. Scarcely a third of these men are on watch at any one time. They do not toil or sweat, but walk around a perfectly cool and well ventilated boiler room, occasionally turning a valve or peeping at a fire through a small hole in the closed front of the fire box, and all the while looking as cool, calm and collected as a sexton in a church. One man attends twelve fires and does it easily.

"The coaling of a big ship is a long, dirty and expensive job, taking up much of the time when the ship is in port, and taking precedence over all other work. The labor of 300 men was required to coal the *Olympic* each trip, and they worked from four to four and one-half days. At a minimum they put in 9,600 hours on the work.

"Now the ship can be 'bunkered' in eight hours, with the labor of only ten men, or 80 hours' labor in all. While the fueling is in progress, other work aboard the ship is not interrupted.

BUNKERING S. S. "MAJESTIC" FROM "S. M. SPALDING," NEW YORK, MAY, 1922.

There is no resulting dirt, and the process goes on silently. A barge or 'tanker' comes alongside, laden with oil; a hose is connected with a pipe in the ship leading to her oil storage tanks; a pumping engine on the barge goes silently to work, and thenceforward the pumping of oil into the ship's tanks at the rate of about 600 tons an hour goes steadily on. The only labor performed by the attendants is watching the tanks, valves and pumps, and shutting off the supply when the tanks are full.

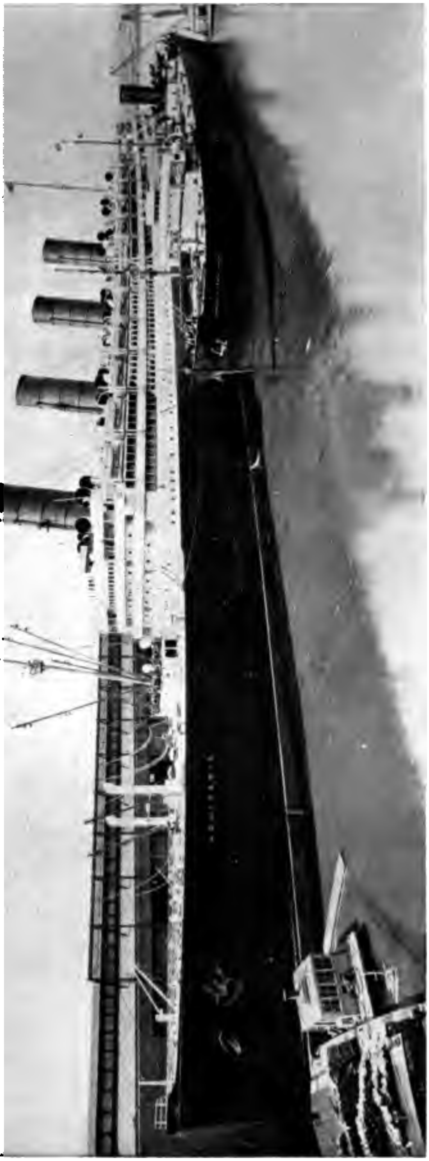
"Recent developments concerning the ship are evidence that she has registered complete success with her oil-burning, for she now comes out with increased tankage for fuel, installed during her layoff, which equips her for taking on sufficient oil at one time to last her on a round voyage, with a comfortable surplus at the end.

"The amount of oil burned by the *Olympic* on a voyage of 3,000 miles from New York to England is about 3,600 tons or about 600 tons a day. The ship's consumption of coal was from 840 to 920 tons a day.

"From time to time there have been printed statements regarding fire hazards on board oil-burning ships, which shipping men declare are unfounded. The oil tanks are nowhere near the fires, and the oil in them is so heavy that it would not readily ignite if a lighted match were thrown into it. Although oil has been used as fuel on passenger ships for several years, a disastrous fire has never been caused by its use in this manner.

"There are five single-ended Scotch boilers and 24 double-ended, each with three furnaces, or a total of 159 furnaces, each 8′-7 9/16″ long and 3′-9″ in diameter. These are located in six boiler rooms, which occupy 320 feet of ship's length.

"When burning coal, the total bunker capacity was 7,577 tons, giving the ship a steaming radius of about 5,000 miles at 20 knots, and about 4,350 miles at 21 knots. Conversion to oil released some 1,000 tons of space for cargo in the old bunkers and the other space has been taken for pump rooms, etc. Burning oil, the steaming radii have been slightly increased, although data is insufficient to give the exact figures. The following



BUNKERING S. S. "AQUITANIA" FROM S. S. "EDWARD L. DOHENY JUNIOR," NEW YORK, JULY, 1920.

comparison between coal and oil gives approximate figures:

21 knots.	*Coal*	*Oil*
Miles per ton	.57	.85
Lbs. per 1 H. P. per hour	1.64	1.12
Number of men in firerooms	246	60
Time required for fueling	4½ days	8 hours

"The most important item of saving in connection with use of oil is not in the matter of the cost of the fuel itself, but in the more constant employment of the ship through shortening of turn-around. This effects very great savings through the more steady employment of the capital invested, which is great. Idle days in port are tremendously expensive, and every operator seeks to eliminate them. A three-weeks round voyage is made possible to the *Olympic* through the time saved in fueling, and *through this alone.* With coal, a full week in port was largely consumed with coaling. About thirty operating days are thus added to a year's total. The importance of this point cannot be too strongly stressed, in consideration of the economic features of employing oil fuel.

"Excellent results in combustion are being obtained, as the *Olympic* steams with an entire absence of smoke and only a thin light gray haze comes from her stacks. Increasingly better results of combustion are being obtained each trip, under the able supervision of the Chief Engineer, Mr. T. H. Thearle, and his assistants. It may be stated that the burning of oil on this giant ship is efficient and economical and that the judgment of her owners in deciding upon the change has been clearly substantiated."

During her first trip on oil from Southampton to New York, in June, 1920, the *Olympic* maintained an average speed of 21.5 knots. Whilst the savings already referred to are very great, there are other factors upon which it is difficult to place a cash value, which in a year would amount to a very large sum, as for example, the cost of repeated paintings due to the dust from coal; wear and tear and renewal of grate bars; coal and ash

S. S. "MAURETANIA" BEING BUNKERED WITH "MEXPET" FUEL OIL IN NEW YORK HARBOR PRIOR TO FIRST EASTBOUND VOYAGE ON OIL; APRIL, 1922.

handling tools and machinery; corrosion of fire-plates, boiler front castings and hanger plates; the wear and tear on coal barge equipment and machinery, and corrosion in bunkers, and the painting of the fire-room.

"The Shipping World" of January 4, 1922, says: "It would be futile to attempt to enumerate the ships in the merchant service that are today oil burning. A study of recent issues of 'Lloyd's Register' serves to show the rapidity of the progress that is being made. Just prior to the War there were about 370 steamers of the Mercantile Marine, representing approximately $1^1/_3$ million tons, burning oil fuel. The last edition of 'Lloyd's Register' includes over 2,530 vessels, totalling over $12\frac{3}{4}$ million tons.

"The popular imagination has, perhaps, been most vividly impressed by the application of fuel oil burning to the huge trans-atlantic greyhounds. The behaviour of the *Aquitania* on her first voyage across the Atlantic under fuel oil aroused considerable interest. The average speed from New York to Cherbourg worked out at 23.28 knots, which is the fastest crossing this vessel has made since the end of the War. A noteworthy feature was the remarkably consistent steadiness of speed throughout the voyage. During the western trip the *Aquitania,* on the third day out, made a spurt to $24\frac{1}{2}$ knots, which she maintained for ten hours. On this voyage she consumed about 3,900 tons of fuel oil as compared with about 5,480 tons of coal."

When there is an intensive demand for commodities, as during 1919 and the early part of 1920, the supply is hampered by inefficient methods. The delays through the coaling of ships were most irritating to a world clamoring for cargo vessels. It was no unusual thing to see a ship tied up at a wharf for five or six days waiting while she was being bunkered with coal. A vessel of similar tonnage could have been bunkered with oil in a few hours, either at dock or from a barge.

The main care in the generation of steam, whether in the boiler of a ship, train, or stationary plant, is to get the maximum of power with the minimum of labor and cost, and the question

for the purchaser of any fuel is not the number of tons or barrels of the commodity, but the amount of effective B. T. U.'s per pound which the fuel contains.

The calorific value of coal varies between 9,000 and 14,000 B. T. U.'s per pound, whilst that of fuel oil varies only slightly and averages about 18,500 B. T. U.'s per pound.

Fuel is a commodity like boots, or soap, and it is in the highest interests of the commerce of any community to use only the best and the most economic fuel for the production of steam.

The main advantages of oil may be briefly indicated:

1. Economy in Labor—Where fuel oil is used in place of coal, either in ships, stationary plants, locomotives or industrial heat treating furnaces, there is a great saving effected in labor. Fuel oil is handled mechanically from the time it leaves the tanker until it is atomized in the furnace or boiler, whereas coal is handled and rehandled many times. Due to the economical handling of fuel oil, not only the fireroom force, but all labor is very materially reduced.

In the mercantile marine, economy is exemplified in the saving in the fireroom force. The largest ship now crossing the Atlantic when fired with coal required 246 men in the boiler room. Since conversion to oil, the number has been reduced to sixty. This does not take into account the saving in men required for bunkering the ship and cleaning after she has been bunkered.

In stationary plants the saving in fire force is well exemplified in a large New England woolen mill. This plant is equipped with twenty-two boilers, aggregating 8,050 horse power. The mill operated two shifts a day and employed a fireroom and coal handling force of eighty-five men; fifty on the day shift and thirty-five on the night shift. When oil was introduced into this plant, the fireroom force was cut to eight men; five on the day shift and three on the night shift.

In industrial plants, such as glass manufacturing, heat treating, etc., the saving in labor, although not so great as in the foregoing classes of industry, is very large.

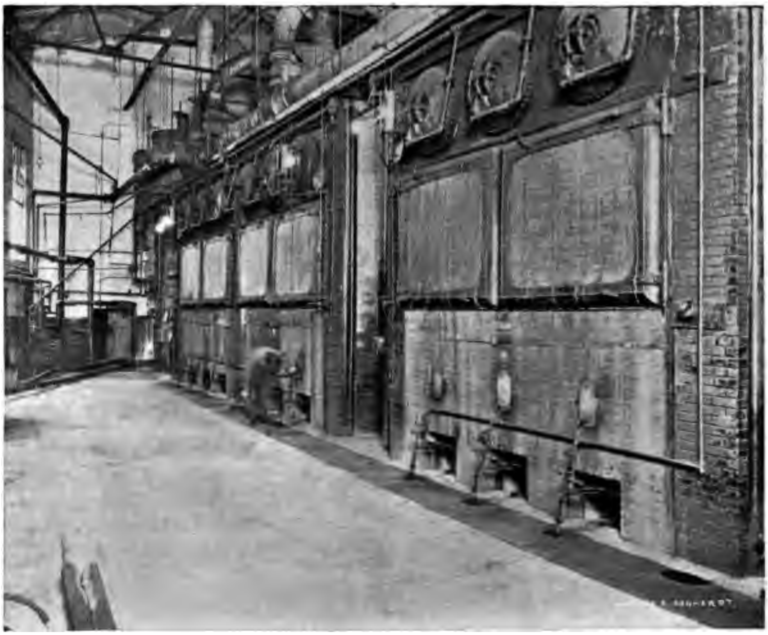
2. Labor More Efficient—Almost every class of work connected with coal necessitates unusual discomfort and arduous toil, which reduces alertness and efficiency. The low temperature of boiler rooms on ships using oil, as contrasted with the stoke-hold of a coal-fired ship, keeps firemen in better physical

HAMMERSLEY PAPER CO., GARFIELD, N. J., BURNING COAL.

condition and increases their powers of attention. In the tropics, these features are most pronounced.

On railways with long and heavy gradients, the speed of a train depends mainly upon the physical endurance of the fireman; with oil, the only thing necessary is the adjustment of a valve, and the fireman is able to assist in keeping a look-out ahead.

3. Higher Boiler Efficiency—Boiler efficiency obtained with coal ranges from 40% to 71%, and with fuel oil from 75% to 82%. The amount of air admitted to a furnace is one of the prime factors in obtaining efficiency. If either an excess or insufficient amount of air is admitted a drop in efficiency is the



HAMMERSLEY PAPER CO., GARFIELD, N. J., BURNING OIL.

result. With coal, on account of the air required for combustion having to pass through an uneven bed of ashes, clinkers, partly consumed coal and green coal, it is impossible to admit the proper amount of air required for perfect combustion, and from 50% to 100% excess air is necessary to get satisfactory results. If less than this amount of air is admitted, the carbon turns to CO instead of CO_2, and the full heating value is not obtained.

In a furnace equipped with fuel oil, the air for combustion

passes through unobstructed openings and is completely mixed with the atomized oil. A very small excess is required to give perfect combustion and a correspondingly higher efficiency can be obtained and maintained at all times.

In hand fired, coal burning boilers, the fire doors are frequently opened, which admits a large volume of cold air into the fire box, with a corresponding chilling of the fires and drop in efficiency. This is avoided with fuel oil. In coal burning boilers there is a large waste due to the unconsumed carbon falling through the grate bars and being drawn out with the ashes; a great deal of heat is wasted in the form of partly consumed coal, when fires are cleaned.

It is safe to say that under ordinary circumstances, on an average, 75% increased boiler capacity can be obtained by using fuel oil, and as the stack area required for burning oil is only 65% of that required for coal, 35% more power can be developed from the same stack area. This is of great importance in plants that have limited stack area and desire to increase their boiler capacity. If coal were used, it would be necessary to construct a new stack and install additional boilers, but by the use of oil, this extra expenditure is not incurred.

The efficiency at which a boiler is being operated depends mainly on the percentage of CO_2 in the resulting gases of combustion. If two boilers, one using coal and the other using fuel oil are equipped with automatic CO_2 recording instruments, the difference in the recorded results obtained is very striking. With fuel oil, from 14% to 15% CO_2 will be obtained for 24 hours, while with coal the percentage of CO_2 will fluctuate hundreds of times per day and will range from 8% to 14%, and each drop recorded will represent a drop in boiler efficiency.

4. Flexibility—A striking advantage obtained by the use of fuel oil is that it enables operators not only in stationary plants and heat treating furnaces, but also on ships, to maintain steady and constant pressure and even temperatures in the boilers. This is not possible with coal. In marine installations, it is possible at all times to have 100% working steam pressure

available which enables the ship to maintain a constant speed; in this way time is saved between ports.

When a coal-burning vessel arrives in port, the same number of fires are naturally not required to operate the winches, etc., as are necessary for propelling the ship, and consequently the fires not required are either banked or drawn entirely, with resulting waste. When an oil-burning vessel arrives in port, the burners in the furnaces not needed are simply turned out and the boilers shut in without loss.

The use of fuel oil in stationary plants enables the engineer to leave his plant standing cold to within a short time before the boilers have to be "cut in on the line;" the burners are then lit and in a few minutes the boiler will be on full working pressure. Fluctuation in boiler loads can be taken care of at a moment's notice by simply turning the oil and steam valves. As soon as the demand ceases, the fires can be turned down immediately to normal, or extinguished entirely. This represents a large saving in plants operating only twelve hours daily, and carrying fires banked the remaining twelve hours, and in plants that have constant demands for increased power for short intervals of time.

The saving during stand-by periods is well exemplified in a large power station in New England. This plant for many months carried two 500 H. P. boilers banked, ready to be "cut in;" but as the demand for this increased power did not arise, all the coal used was wasted. The cost of banking these boilers was about $500 a week, or approximately $2,000 a month.

In metallurgical and industrial processes, such as heat treating furnaces, glass making, etc., a more constant and uniform temperature can be maintained at all times in the furnace with oil, which results in a more uniform product and a great saving in time and material.

In oil burning locomotives, constant pressure can be maintained, and increased capacity developed when it is required. When the emergency is over, the burners can be turned down without any waste.

5. Absence of Dirt—In all types of plants where fuel oil is used, the absence of dirt, coal dust and ashes insures clean boiler rooms, reduces wear and tear on pumps and other machinery; and the cost of removing and handling ashes is eliminated. On naval ships as well as on the merchant marine, many men are employed, not only to put the coal aboard, but

WHITTENTON MANUFACTURING CO., TAUNTON, MASS., BURNING COAL.

to clean the ship when bunkering is completed. The cost involved in frequently painting ships is a considerable item which is avoided when fuel oil is used.

On railroads and oil-burning locomotives the absence of smoke, soot and ashes serves to keep the rolling stock clean, and windows can be opened when desirable.

Laundries, bakeries, schools, hospitals, office buildings and all

factories where cleanliness is a necessity, are finding oil indispensable. New laws that are being enforced, in regard to smoke from plants, are raising serious problems, and thousands of dollars are spent annually in fines on account of the smoke nuisance. In London, 70,000 tons of soot are deposited yearly.

WHITTENTON MANUFACTURING CO., TAUNTON, MASS., BURNING OIL.

6. Reduced Cost in Maintenance and Equipment—When fuel oil is used no grate bars or firing tools are necessary, and accordingly the furnace lining and brick work last longer. Burning out of grate bars in a coal fire, especially where automatic stokers are used, is a constant source of expense. The tools for firing and removing clinkers damage the furnace lining.

In marine use, there are fewer repairs to the boilers, due to uniform temperature in the furnace and combustion chambers. There is no corrosion of boiler plates, fire fronts, etc., and no ash or coal handling machinery to purchase, renew, or repair.

Plants designed for fuel oil do not require the great investment in fuel handling devices that are needed for coal. There are no expensive conveying or hoisting machines necessary.

GORHAM MANUFACTURING CO., PROVIDENCE, R. I., BURNING COAL.

The first cost of machinery of this kind, when coal is used, and the necessary repairs and renewals are very large items in boiler operating costs. Available space that would ordinarily be used for coal pockets can be used for more advantageous purposes, as oil can be stored underground.

7. **Bunkering**—Oil insures quick bunkering from shore or by lighter, during day or night. Warships can take on a supply of oil in port or at sea under cleaner conditions and at a greatly accelerated rate. After the hose connections have been made,

the oil is rapidly pumped without the arduous manual labor involved in the handling of coal. Bunkering with coal at night, necessitating the glare of lights, renders the vessel a conspicuous object for attack; with oil this danger is avoided.

8. Saving in Space—This saving is of most importance in the mercantile marine and navy. A ton of coal occupies 43 cubic

GORHAM MAUUFACTURING CO., PROVIDENCE, R. I., BURNING OIL.

feet, while a ton of oil requires 38 cubic feet. This must be taken in conjunction with the fact that the boiler efficiency with coal will not average over 62%, and that with oil about 78%. Furthermore, as six tons of oil are equivalent, in effective heat value, to eleven tons of coal, due to fuel oil having higher calorific value and more efficient combustion, a saving of 40% in weight is obtained. There is also an additional saving in space, as oil can be stored in any convenient place, such as the ship's double bottom, making available the space that would otherwise be used for carrying cargo.

About 75% fewer men are required to operate an oil-burning vessel than a coal-burning vessel, and the room that would ordinarily be occupied by the firemen is available for additional cargo space or other passengers.

9. Conducive to Safety—Nine per cent of all ocean cargoes of coal of 2,000 tons or over, catch fire from spontaneous combustion. Fuel oil is not subject to spontaneous combustion. The shifting of coal in heavy weather at sea is dangerous.

The absence of smoke enables vessels using fuel oil to move with less danger of detection, and if smoke is wanted to mask fleet operations, oil can be made to furnish the blackest and most lasting smoke. When oil is used by railways, the absence of sparks removes the danger of setting fire to forests, grain fields, straw stacks, and barns. Oil can be stored underground, and at such distances from manufacturing plants as to minimize the danger of fire.

10. Wastage Avoided—Waste is eliminated by using oil. Coal, especially the softer varieties, disintegrates in storage. If coal is not protected from rain, the loss from this cause is very great. The amount of inert matter in the form of ash carried with coal may be taken at 5%, so that a vessel with 2,000 tons of bunkered coal is shipping 100 tons of useless material.

In switching and shunting operations on railways, engines have frequently to stand idle for hours; with oil, the burners can be cut down to a minimum. There is usually a wastage of coal between shipment and consumption; coal used in banking fires represents loss. Stack temperatures are relatively higher with coal than with oil due to the increased draft that is necessary, which results in waste, and therefore additional cost.

FUEL OIL INSTALLATIONS FOR STATIONARY PLANTS

In considering the possibility of converting from coal to oil fuel in stationary plants, a number of questions present themselves to the engineer, the chief of which are:

1. How many barrels of oil are equivalent to a ton of coal?

2. What economies and savings will result with oil fuel?
3. What equipment is necessary?
4. What changes will be necessary in the boiler arrangement?

The answers to these questions can be given here only in a general way, and all prospective users of fuel oil should consult the engineering department of one of the large fuel oil marketers in their district, or one of the "Oil Burning Equipment Companies" who maintain specially trained men for this purpose.

1. How many barrels of oil are equivalent to a ton of coal?—This depends on the quality of the coal, and the average daily efficiency obtained. In considering the question of efficiency, distinction must be drawn between the efficiency under test conditions and the efficiency obtained under operating conditions, because it is the operating efficiency that counts. With coal, the efficiency under test conditions is higher than everyday efficiency, as each man is doing his utmost so that the report may be favorable. With oil, everyday conditions are test conditions, as each man has time to watch the operation of his boilers to keep them at their highest efficiency.

To be conservative, it is safe to assume for oil burning an average efficiency of 78%, which is equivalent to an evaporation of 14.8 pounds of water from and at 212° F. per pound of oil.

Oil is bought by gallons or barrels, and not by weight; and Mexican fuel oils contain more pounds per gallon and more B. T. U.s per gallon than oils from the fields of the United States. Oil should be uniform in gravity, have uniform heat value, and contain a minimum of moisture and sediment.

The fuel oil from the Southern Fields of Mexico ranges between 14° and 16° Baumé. It is uniform in heating value and gravity; and contains practically no moisture or sediment. It weighs approximately 8 lbs. per gallon. After long experience and varied tests, it has been found by this Company, in general practice, that four barrels of Mexican fuel oil are equal to one gross ton of good bituminous coal.

2. What economies and savings will result with fuel oil?—The advantages of fuel oil and the savings which result are

discussed earlier in this chapter; it is therefore unnecessary to repeat them here.

3. What equipment is necessary—With the increased use of fuel oil, most cities and towns have passed ordinances, and insurance companies have drawn up rules governing the storage and handling of fuel oil. These should be consulted.

The equipment necessary for an oil burning installation is as follows:

(a) Storage Tanks.
(b) Pumping System.
(c) Oil Heating System.
(d) Furnaces.
(e) Burners.

(a) *Storage Tanks*—One or more tanks should be installed, depending on the amount of oil consumed and the frequency of deliveries. It is not advisable to have a storage capacity of less than two weeks' supply, preferably one month, and the storage tanks should be located, where possible, in such a manner that the oil may be unloaded from the tank car or truck by gravity. Fuel oil from the Southern Fields of Mexico is handled most economically at a temperature of 90° F., and it is advisable to provide a small steam coil around the suction pipe in the storage tank to maintain this temperature for the oil leaving the tank. In cold climates a flat coil is sometimes installed in the bottom of the tank, or the tank is divided into compartments and the oil in one compartment heated. The exhaust steam from the oil feed pumps is usually sufficient for this purpose.

It is good practice to install storage tanks below the level of the burners, and in congested districts where the fire hazard is unusually great the tanks should be buried. Steel tanks are the most economical if built above ground, or when buried, if they are of small capacity. For large underground storage, concrete tanks are popular; if a rich mixture is used, and the tanks properly designed, they are economical and have proven very satisfactory. No oil-proofing compound is necessary, as it has been demonstrated that fuel oil does not affect the concrete,

(b) *Pumping System*—Gravity supply to burners is not advisable, and is usually prohibited by insurance companies. A pump, therefore, is required to draw the oil from the storage tank and deliver it to the burner at a uniform rate and pressure. The most common type in use is the duplex pump. To insure continuity of operations, it is advisable to provide a duplicate pump set, each pump being of sufficient capacity to deliver the required amount of oil to the burners at from 50% to 75% of its rated speed. An installation of this kind enables the operator to repair one of the pumps when necessary without interfering with the operation of the plant.

The pressure at which the pump delivers the oil to the burners varies with the type of burner used. With steam atomizing burners, the usual pressure is from 40 to 80 pounds, while with mechanical burners the pressure will range from 80 to 120 pounds.

Pumps should be equipped with automatic governors and with strainers. The automatic governors control the amount of oil to be delivered to the burners, and take care of any fluctuation in boiler pressure, thus enabling a plant to maintain practically uniform boiler pressure at varying loads. Straíners are advisable and should be installed on the discharge side of the pump, so that any foreign matter in the oil may be caught before going to the burners, and thus prevent clogging. The suction line to the pumps is connected directly with the supply tank, and the discharge line from the pumps to the burners should be returned to the supply tank. The advantage of a circulating system of this kind is that if, at any time, the plant is shut down, and the oil allowed to become cold in the supply lines, the pumps can be started and the hot oil circulated from the supply tank through the supply lines and back into the supply tank before going to the burners. A thermometer should be installed on the discharge line from the pumps so that the engineer will always be informed of the temperature of the oil being supplied to the burners.

(c) *Oil Heating System*—An important factor in efficient oil-burning is the temperature to which the oil is heated before being delivered to the burners; and manufacturers of fuel oil equipment now supply duplicate pump sets complete with duplicate heaters for pre-heating oil to the proper temperature. The heat medium is generally the exhaust steam from the oil feed pumps, but in some cases in mechanical installation it is necessary to use additional live steam to bring the oil to the proper temperature. The temperature varies to some extent according to the type of burner used, and with Mexican fuel oil as used in steam atomizing burners, best results will be obtained with temperatures of 150° to 170° F. With mechanical burners it is necessary to use higher temperatures, which vary from 180° to 212° F., according to the type of mechanical burner used.

(d) *Furnace Design*—The most important part of any fuel burning system is the furnace design, and this point cannot be given too careful consideration. Furnace designs vary for different installations, and must be designed to meet specific conditions for which they are intended. They are governed to a great extent by the following factors:

The type of boiler.

The type of burner.

The number of burners to be used.

The available furnace draft.

The capacity at which the boiler is to be operated.

Successful and economical burning of fuel oil requires a larger furnace volume than coal. Theoretically, for proper combustion of one pound of fuel oil, 14 pounds of air are required, as compared with 11 pounds of air per pound of coal. In practice, it is not possible to burn oil with this quantity of air, but with good design 25% excess should be the maximum.

It is impossible to judge accurately, from the appearance of the flame, or by the absence of smoke in the gases leaving the stack, whether the correct amount of air is being used, and the only certain method of determining whether the maximum

efficiency is being obtained is by means of a flue gas analysis, or the use of a CO_2 recorder. 14% to 15% of CO_2 in the flue gases represents good average efficiency with oil.

In the absence of CO_2 recorders, an experienced fireman can regulate the fire, with a fair degree of accuracy, by observing the quality of the flame and the gases leaving the stack. The presence of a slight haze at the stack usually indicates good combustion. It is highly advisable, however, to install automatic CO_2 recorders and draft gauges; and the small additional cost for this equipment will soon be recovered by the increased and uniform efficiency obtained.

The furnace should be so designed that there will be no impinging action of the flame on the tubes or shell of the boilers, or on the brickwork, and in water tube boilers the first pass of the boiler should be located directly over the furnace in order that the heating surface may absorb the radiant energy from the incandescent firebrick.

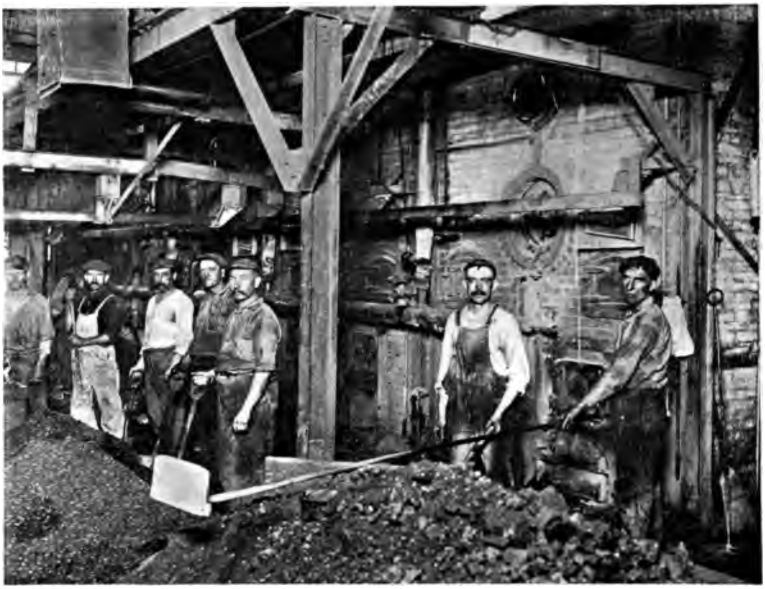
For B. & W. and Stirling boilers some types of burners are installed so that they fire "backshot"; that is, the burners are set in front of a bridge wall at the back of the furnace and fired towards the front of the boiler. In general, however, the burners are installed in the furnace front. With short settings it is sometimes advisable to install Dutch ovens to insure complete combustion of the oil before reaching the boiler surface, as in the case of vertical boiler settings.

The velocity of gases through the furnace should be kept as low as possible, and as a basis of calculation it is usually desirable to have approximately one cubic foot of combustion space per pound of oil burned per hour. This figure applies only to boilers where the available furnace draft is less than one-tenth of an inch, and the velocity of the air through the furnace, when running at rating, is about seven feet per second.

In general, with a large combustion space, the boiler can be operated more efficiently at a higher rating.

In furnace designs where steam atomizing burners are used, the air for combustion is admitted through openings left in the brick-

work in the furnace floor under the burner; and in some cases with steam atomizing burners, it is found advisable to allow the admission of a certain amount of air for combustion through the furnace front around the burner. This latter is usually obtained by inserting a four-inch pipe in the boiler front through which



MANHATTAN RUBBER MANUFACTURING CO., PASSAIC, N. J., BURNING COAL.

the burner passes. This has the additional advantage of permitting easy removal of the burner. In mechanical burners all the air for combustion is admitted through a specially designed furnace front around the burner.

The openings in the brickwork are usually 1″ in width, commencing at the front wall and extending into the furnace to a depth not greater than four feet.

When boilers are set sufficiently high to allow for proper furnace design, the air inlet is through the fire box doors, but with low settings it is usually necessary to lower the furnace floor, brick up the fire doors (allowing only a peephole), and set the burners in the ash pit doors, in which case air ducts would

MANHATTAN RUBBER MANUFACTURING CO., PASSAIC, N. J., BURNING OIL.

have to be constructed to allow admission of the air below the furnace floor.

The total area of air openings in the furnace will vary with the draft conditions, but ordinarily three square inches is allowed per boiler horsepower, and the draft cut down at the uptake to give the desired rating. In properly designed furnaces, the air admitted to the boilers for combustion should not be regulated by closing the ash pit doors, but should be regulated almost

entirely by opening and closing the damper. In this way a much closer regulation of the proper amount of air for combustion can be obtained, furnace velocities reduced, and stack losses brought down to a minimum.

The ideal furnace is that which increases in cross sectional area with the flow of gases, with the floor rising slightly towards the back to deflect the gases upwards.

The walls should be lined with a good quality refractory brick to withstand the temperature conditions, and it is advisable to put a layer of insulating brick between the furnace lining and the outside common brick. The setting should be made absolutely tight to prevent leakage of air.

(e) *Burners*—There are many types of burners on the market, but they may be divided into the following general classifications:

Mechanical Atomizers.

Steam or Air Atomizers.

The Steam or Air Atomizing burners may be further divided into Outside Mixing and Inside Mixing types.

With Mechanical Atomizing Burners, the oil, after pre-heating, is forced under pressure through a burner so designed as to break the oil up into a very fine spray. This is sometimes attained by imparting a rotary motion to the oil when passing through the burner, or by means of a specially designed tip.

With Steam or Air Atomizing Burners the heated oil is sprayed into the furnace and atomized upon issuing from the tip of the burner by the action of the steam or air. In most stationary plants steam atomizing burners are used. Until a few years ago mechanical burners were used almost exclusively in marine installations where fresh water is an important factor, but in the last two years, mechanical burners have been improved so that they are adaptable and are used very successfully for land installations. It has been found in practice that nothing is gained by using compressed air for atomizing, as the extra initial cost of compressors and of operating them is found to be greater than steam furnished direct for atomizing the oil. On

marine installation, where fresh water is an important factor, mechanical burners, which require no steam for atomizing, are almost invariably used. The function of any burner is to atomize the oil so that the oil particles will present the maximum of surface for combustion. In selecting an oil burner, the amount of steam used for atomizing is the principal factor to consider. The steam consumption of various burners on the market varies from 1% to 3%, but with careless operation of burners, as high as 5% may be used.

Burners are usually designed for greatest efficiency at a certain horsepower, and the number of burners required will depend upon the horsepower which it is required to develop.

4. Changes necessary in boiler arrangement—Prior to the advent of Mexican fuel oil in the markets of the United States, it was not considered advisable, owing to the uncertainty of supply, to alter the furnaces of coal burning boilers to any great extent, thus preventing a change from oil to coal on short notice. Since the Mexican fields have been developed, fuel oil distributing terminals have been established at practically every large port on the Atlantic seaboard and the Gulf, where very large supplies of fuel oil are carried at all times. Manufacturers contemplating using fuel oil are assured of a constant supply, and can therefore take advantage of the experience gained during the past seven years by engineers who have specialized on oil burning, and equip their boiler rooms according to the most modern ideas, and thus secure the best results.

During 1921, many who were considering the use of fuel oil were deterred by the reports, sedulously circulated, on the exhaustion of the Mexican oil fields. The best reply to these sinister stories is that during 1921 the Mexican fields yielded 195,064,000 barrels of oil, or nearly one-half the yield of the fields of the United States. There are indications of oil in practically every state in Mexico, and there are houses built of asphalt, and innumerable seepages in places where no rig has yet been built. The amount of oil yet to be taken from the

Mexican fields is enormous, and the major portion of the lands has not even been tested by the drill.

During the early days in the oil industry, people were warned against the purchase of lamps, on the grounds that the supply of kerosene would soon be exhausted, and the timid were only gradually weaned from candles and other less attractive means of lighting, by discovering that the prophets were wrong. The same story was heard of the Russian oil fields. Immediately before the war, long prophetic articles were written on the exhaustion of the Baku fields. The anxiety to get oil lands around Baku today is the most effective reply to these misleading criticisms. There is nothing unusual in what has been written regarding the Mexican oil fields; meantime, the production of these fields increases.

CHAPTER IX

GEOGRAPHICAL DISTRIBUTION OF PETROLEUM

IN writing of the geographical distribution of petroleum in 1922, one labors under peculiar difficulties owing to what Coleridge would call "temporal or fluxional boundaries." The new map of the world may take as long to determine as the destruction of the old one. It seems, therefore, more practicable, in the absence of final boundary decisions, to use pre-war names, save in instances where there appears to be no longer cause for doubt. Alsace and Lorraine are now definitely included in France, but the boundaries of some countries are still liable to sudden fluctuations, and any reference to undefined or provisionally defined lands will be from the point of view of pre-war maps.

The chief oil fields of the world are summarized in this chapter, and the figures relating to production are taken from official sources where these are available.

NORTH AMERICA

Canada—Oil and gas are found in many places throughout the Dominion of Canada. Attention was first attracted to the County of Lambton, at the extreme west of Ontario, when James Shaw discovered oil there in 1861. The first flowing well was drilled at Oil Springs in 1862, and later the Petrolia Field was opened. Ontario oil is of good grade, but carries considerable sulphur. The gravity varies from 28° to 36° Baumé.

The chief fields in Ontario are the Mosa, Petrolia-Enniskillen, Oil Springs, and Bothwell.

The presence of sulphur in the Ontario wells created peculiar difficulties for the industry in Canada. The odor from the oil

was so penetrating and offensive that for a long time it was practically useless. The smell, though every known eliminating process was tried, defied science. Shippers refused to handle it, as the odor was all-pervasive, tainting bacon, flour, and other commodities which were in its neighborhood. It was known as ''sulphur oil,'' not to mention the malodorous epithet ''skunk oil,'' which it also bore. Scientific men labored with great diligence, and ultimately succeeded in overcoming this feature. The oil industry is more successful in Ontario than in any other part of Canada. Many of the wells do not exceed 500 feet in depth.

Recently there has been some production obtained from New Brunswick, and the most important area is the Stony Creek Field, in Albert County. The production for 1921 in New Brunswick was 7,579 barrels.

The largest petroleum area in Canada lies in the region of the Athabasca, Mackenzie and Peace Rivers, in the northwestern part of the Dominion. ''The interest shown recently in western Canada as a possible oil district is due mainly to the tar sands on the Athabasca River. The sands are saturated with asphaltum and heavy oil, and contain about fourteen gallons of oil to the ton. They crop out along the river for 100 miles and cover an area of 2,000 square miles, ranging in thickness from 13 to 200 feet.'' This territory is being prospected. There are expectations of obtaining oil at Fort Norman, Edmonton and other centers.

In 1914, Calgary repeated in miniature the history of Oil City after Drake's discovery in 1859. Thirty miles distant from Calgary, oil in small quantities had been struck, and the inevitable boom made its appearance. The climax was reached on May 16th, when the city had become oil crazy. A contemporary writer says, ''no one knows how much money was collected since there was no time to count it. Waste-baskets were filled with banknotes and checks, emptied, and filled again and again.'' But the prospective wealth from this source did not mature.

The total production of Canada in 1921 was 190,000 barrels.

United States—The United States' production of petroleum

rose in 1902 above that of Russia, and since that date there has been a phenomenal increase, until in 1921 the yield amounted to 469,639,000 barrels. The existence of petroleum in the United States over a large area had been known from an early period, but the drilling of the first well by Colonel Drake marked the beginning of a new epoch in the history of oil; and Drake's discovery of the source of petroleum is intimately connected with the progressive and intensive character of the far-flung commercial activities of our modern life. The oil industry has been developed more thoroughly in the United States than in any other part of the world, and many acres of land designated "waste" have been proven to be oil-bearing. Each fresh development in the industry has attracted the keenest minds, with the result that every aspect of the business, from prospecting to distributing, is planned on the most efficient and scientific lines.

It has been customary to group the fields of the United States according to geographical position, but as these have extended, the boundaries have become less distinctive, and attention is now directed more to the character of the oil than to the geographical position of the field. The oil-fields of the United States had the most active year in their history during 1921, and new high records were made.

Appalachian Field—The Appalachian Oil Field, discovered in 1859, was the first great oil field in the world to be extensively developed. Its area is very large, but it has long since ceased to be the most important from the point of view of production. Surface indications of oil are not numerous; but oil from these 'seeps' was gathered by Indians and early settlers and used for medicinal purposes. The reservoir rocks are mainly sandstone or conglomerate layers, and the area of oil pools is about 2,500 square miles. From 1859 to 1875 the entire American production came from this field, and until 1885 it furnished more than 98% of the total yield. It embraces all the oil pools east of central Ohio and north of central Alabama, including those of New York, Pennsylvania, West Virginia, southeastern Ohio, Kentucky, Tennessee, and northern Alabama. The oil is nearly all classed as

"Pennsylvania" grade. It has a paraffin base, and averages about 43° Baumé, yielding by ordinary refining methods a high percentage of gasoline and illuminating oils.

It is significant that none of the newer fields in the world have

By Courtesy of U. S. Geological Survey
HOPE WELL, WEST VIRGINIA, DEEPEST IN THE WORLD (7597 FEET).

produced a grade as high as "Pennsylvania oil." Owing to its valuable character, which is enhanced by its proximity to good markets, the production is kept alive by cleaning and deepening the wells, or by obtaining oil from shallow sands, which were regarded as too small when the wells were first drilled. The life of the wells is phenomenally long, and some of those at Titus-

ville, in the neighborhood of the original "Drake" well, were being pumped a few years ago. The "Triangle" well was the first commercial well drilled in New York. It was brought in over forty years ago, and recently was yielding an average of about 1/8 of a barrel per day. Production in this field reached its maximum in 1900, with a total of 36,295,433 barrels; in 1921 the yield was 30,574,000 barrels.

The Lima-Indiana or Trenton Field—The Lima-Indiana Field, discovered in 1886, lies northwest of the Appalachian range, and includes all areas of production from Lake Erie to a point near Marion, Indiana. It is said that 30,000 wells have been drilled in the Indiana portion of the Trenton Field, and a larger number in Ohio. Surface indications of oil are rare. The most productive oil-bearing beds are in the Trenton limestone, the oldest known oil-bearing rock in the United States. In the Ohio fields the depth of the Trenton limestone ranges from 1,000 to 1,500 feet, but in Indiana the depth is more uniform, and is about 1,000 feet. The Trenton limestone in the producing region has a high porosity. The oil has a paraffin base averaging about 39° Baumé and contains sulphur. Many elaborate experiments were conducted by chemists before a satisfactory plan was discovered of eliminating the sulphur. Ultimately the Frasch method was successful. Since 1904, when the yield was 24,689,184 barrels, there has been a decline. The production in 1921 was 2,411,000 barrels.

The Illinois Field—The Illinois Field, discovered in 1879, lies wholly within the state. The principal area of oil production is in the southeast corner of the state, in Clark, Cumberland, Lawrence, Jasper, Crawford and Wabash Counties. In addition, there are a number of pools in the central and western parts of the state. Surface indications of oil are meagre. The first valuable deposits of oil found in Illinois were discovered near Litchfield, by the Litchfield Coal Company, towards the end of 1879; but it was not until 1905 that oil in large quantities was obtained.

The petroleum of this territory contains varying proportions of both asphalt and paraffin. It ranges in gravity from 27° to

OIL TANK ON FIRE.

37° Baumé, and is relatively free from sulphur. There are six or more productive sands in the southeastern fields. The output in 1908 reached a maximum of 33,686,238 barrels. In 1921 the yield in this field was 10,935,000 barrels.

Mid-Continent Field—The Mid-Continent Field, discovered in 1903, includes the oil fields of Kansas, Oklahoma, Northern and

MID-CONTINENT OIL FIELD.

Central Texas, and Northern Louisiana and Arkansas. During the last few years there has been a gigantic increase in the production of oil in this territory, and the oil saturation is greater than in most other fields in the United States. For convenience, the field may be divided into four sub-sections:

1. Kansas
2. Oklahoma
3. Northern and Central Texas
4. Northern Louisiana and Arkansas

1. Operations have been carried on in Kansas since 1865, but no very great advance in production took place until 1904, when the amount mined was more than four times that of the preceding year. The quantity of oil marketed in 1917 was 36,536,125, a gain of 27,798,048 barrels compared with 1916.

CUSHING OIL FIELD.

The oil ranges in gravity from 23.1° to 30.3° Baumé. The main producing areas where the yield is over 10,000 barrels daily are: El Dorado - Towanda, Florence - Covert, Peabody - Elbing and Augusta-Fox Bush. The production in Kansas for 1921 was 36,232,000 barrels.

2. Oklahoma and California, at the time of writing, are competing for the premier place as producing states. Each of these

states is averaging over 330,000 barrels daily. The gravity of the oil in Oklahoma ranges from 30.3° to 40.9° Baumé. Two of the most famous pools in Oklahoma have been the Cushing and Glen Pools. There is a well known as the "Gasoline Well" near Cushing, where the oil is said to have a gravity of over 55° Baumé. The districts in Oklahoma yielding more than 10,000 barrels daily are: Osage, Lyons-Quinn, Hewitt, Cushing, Healdton, North Okmulgee County, Duncan and Yale. The yield of oil in Oklahoma for 1921 was 113,978,000 barrels.

MEXIA OIL FIELD, CENTRAL TEXAS.

3. The oil in Northern and Central Texas ranges in gravity from 25.9° to 44.9° Baumé. The oil of Burkburnett and the Ranger region is of exceptionally high grade. The former is rich in gasoline; the latter ranges from 34° to 40° Baumé, and is olive green in color. The most spectacular feature in Central Texas in 1921 was the drilling of the Mexia field. At the time of writing Mexia yields about 90,000 barrels daily. In the Currie-Wortham region, which is "wildcat territory," three producing wells were reported at the end of March, 1922. The districts in Northern and Central Texas where the daily production exceeds 10,000 barrels are: Mexia, Stephens County, Burk-

burnett, Electra and Ranger. In Northern and Central Texas the total production for 1921 was 70,892,000 barrels.

4. In Northern Louisiana, gas seepages found in water pools in Caddo Lake, northwest of Shreveport, led to drilling, where oil of high grade issued in gushers. The areas in Louisiana where production of 10,000 barrels a day is obtained are: Haynesville, Homer and Caddo. The El Dorado field in Arkan-

OKLAHOMA OIL FIELD.

sas first yielded oil in March, 1921. The production during ten months was 10,190,000 barrels. The yield of oil in Northern Louisiana and Arkansas for 1921 was 34,983,000 barrels. The total production of the Mid-Continent field for 1921 amounted to 256,085,000 barrels.

Gulf Coast Field—The Gulf Coast Field, discovered in 1900, includes the gulf coastal plain of Texas and Louisiana. The oil has an asphaltic base, and contains sulphur. At Somerset there is a field which yields light oil. The oil is found in domes many

of which show quaquaversal structure. The maximum production from the pools is soon reached, which is followed by a steady decline. The sulphur in the oil is higher than in the Lima-Indiana Field, though it is in the form of sulphuretted hydrogen, and is less difficult to remove. The gravity ranges from 15° to 30° Baumé and averages about 22° Baumé. At Spindle Top, in South Texas, about three miles south of Beaumont, there is a low mound covering about 225 acres, which rises some fifteen feet above the surrounding flat country. Gas escapes and sulphur incrustations had been noted by A. F. Lucas, and in 1901, when he was prospecting for sulphur, the famous Lucas Well was struck, at 1,139 feet, which proved to be one of the greatest gushers in the United States. It yielded 75,000 barrels a day. This well brought the Texas field into prominence. The production for Texas in 1900 was 836,039; but after the advertisement that was given by the Lucas gusher, the yield in 1902 reached the high figure of 18,083,658 barrels. The peak year of this period was 1905, after which there was a rapid decline. A second period of development began in 1913, when deeper drilling led to the striking of large gushers, and the production rose from 15,009,478 in 1913, to 38,750,031 in 1919. The districts which yield more than 10,000 barrels daily are: West Columbia, Orange County, Hull and Goose Creek. The production in 1921 was 34,160,000 barrels.

Rocky Mountain Field—The Rocky Mountain Field, discovered in 1876, embraces all petroleum areas in Wyoming, Colorado and Montana, as well as a number of areas of prospective production in Utah and New Mexico. Wyoming is the most important of all the fields, with Salt Creek as the most productive. It yields a high grade paraffin and is greatly prized because of its gasoline content. There are many oil and gas seepages in the shale in Salt Creek, as well as ozokerite deposits similar to those in Galicia; within the known oil pools at Salt Creek there are no dry holes.

The production of Colorado has never been large, and has been dwarfed by Wyoming; but in the Boulder oil district of Colo-

rado there has been found oil of about 42° Baumé, and the De-Beque field produces an oil with a paraffin base of 37° Baumé.

The State of Montana has not been fully prospected. Cat Creek has a small production of over 4,000 barrels daily.

The oils from the older strata in the Rocky Mountain Field range in gravity from 18° to 24° Baumé, and are of asphalt base. Those from the more recent strata range between 32° and 48° Baumé, and are of paraffin base and valuable for refining.

By Courtesy of U. S. Geological Survey
OIL FIELD IN ORANGE COUNTY, CALIFORNIA.

The Rocky Mountain Field in 1921 yielded 20,765,000 barrels.

California Field—The California Field, discovered in 1892, lies between Coalinga and the Puente Hills, a belt of land about 225 miles long. The wells in this belt are among the most prolific in the United States. Oil seeps are numerous, and the asphalt beds cover wide areas. From many points of view, the California fields resemble those of Europe and Asia, rather than those of the United States. The oil contains much asphalt, and comparatively little paraffin, though there are individual wells yielding a

large proportion of the lighter oils. There are almost 10,000 producing wells in California. The districts where the yield is over 10,000 barrels daily are: Midwest-Sunset, Whittier-Fullerton, Coalinga, Kern River, Huntington Beach, Lompoc and Santa Maria. The total yield for the California field in 1921 was 114,709,000 barrels.

Not satisfied with drilling on land, exploratory work was

SUMMERLAND, SANTA BARBARA, CALIFORNIA.

carried on under the sea at Summerland, where oil has been obtained in small quantities beneath the Pacific seabed. The first well was sunk in 1896, and several hundred wells have been drilled from derricks erected on piers, which extend a thousand feet into the surf. They range in depth from 100 to more than 600 feet. The spectacle of oil being pumped from beneath the sea is somewhat unique, and the development of the work is favored by a sea of unruffled calm.

According to the United States Geological Survey, the total production in the United States from 1859 to Dec. 31, 1921, amounted to 5,899,332,000 barrels.

Alaska—Oil is found at several places along the Pacific coast in Alaska. Several wells have been drilled in the Katalla field, but the production is small, though the oil is rich in gasoline and has a gravity of 39° Baumé. There are several other fields where the indications of petroleum are very promising.

SHALE IN THE UNITED STATES—When the world is assured that the United States has only a supply of petroleum at the present rate of consumption for twenty-five years, it seems to be forgotten that the oil shales of the country are an asset of great value and capable of yielding oil in enormous quantities. To estimate the amount of petroleum beneath the surface is a daring feat. An easier task is to calculate the amount of recoverable petroleum from shale.

In the *Petroleum Age,* Vol. 7, No. 4, an estimate of the production of the shales in Colorado alone was given which may be cited here:

"It is estimated that the total deposits of shale in Colorado alone amount to 38,000,000,000 tons, and allowing 60 per cent. recovery, the shale available for mining and treatment will total over 23,000,000,000 tons, and a barrel of oil to a ton would yield 23,000,000,000 barrels from Colorado shale alone. There are about 252,000 oil wells in the United States, with an average daily production of less than 5 barrels per well. If 200 oil-shale plants were operating, each treating 2,000 tons of rock daily, there would be an annual production of about 120,000,000 barrels of oil, or the equivalent of the petroleum output of nearly one-third of the oil-producing wells."

Mexico—Twenty-one years ago, when oil was first discovered in Mexico in commercial quantities by the Mexican Petroleum Company of California, Mexico was not generally considered a possible field for development. During the years between 1901 and 1921 Mexico has advanced to the position of second producer of oil in the world, and the total output from 1901 to 1921

amounted to over 725,000,000 barrels; in 1921 the production was 195,064,000 barrels. As the principal holdings of this Company are in Mexico, a large section of this book has been devoted to its properties.

It would be inappropriate here to make more than a general statement of the magnitude of the oil business in Mexico. There

CLEARING JUNGLE FOR ROAD BETWEEN CERRO AZUL AND CHAPOPOTE NUÑEZ.

were 86 producing oil companies in 1921, and 17 of these in 1920 shipped over one million barrels of oil each.

The chief producing districts are:

1. The Panuco River region, which includes the Ebano, Panuco, and Topila Fields.
2. The Southern Fields region, which embraces all pools between San Geronimo and Alamo.
3. The Tehuantepec-Tabasco region.

TIERRA BLANCA NO. 1, DRILLED MAY 22, 1921.

There are striking indications of oil in many other parts of Mexico, but little development work has yet taken place, owing to the amazingly rich territory between the Panuco and the Tuxpam Rivers.

The oil in the Southern Fields is a mixed-base petroleum, and ranges from 19° to 21° Baumé. The highest grade of oil is obtained from the Tehuantepec-Tabasco region, where the gravity is between 25° and 32° Baumé; but the quantity of oil obtained from the wells is small.

The most noteworthy features of the main Mexican fields are the high average yield per well, and the gusher conditions which eliminate pumps, the wells producing under their own hydrostatic and gas pressure. There are in the United States over 250,000 wells, and these average less than five barrels per day. The three hundred wells in Mexico in 1920 averaged 1,800 barrels per day. The oil comes from the wells at a temperature varying from 90° to 180° F., which lowers the viscosity and permits the oil to flow freely.

CENTRAL AMERICA

The oil fields of Mexico and deposits in Colombia have stimulated prospectors to search in Central America for indications of oil. Development work has recently been undertaken in Panama, near Bocas del Torro, and investigations are being made in Guatemala, Honduras, Salvador, Nicaragua, and Costa Rica.

THE WEST INDIES

Cuba—Asphalt, pitch and oil seeps have been known to exist in Cuba for many years, and have been reported from every province in the island. They extend over a distance of 475 miles.

Cuba gained in 1917 for the first time a place among the world's oil producers, and the amount of crude petroleum marketed in that year was 19,167 barrels. The chief source of production was from a field near Bacuranao, about 15 miles north-

east of Havana. The oil is dark in color, and ranges in gravity from 25° to 27° Baumé. When refined it yields 12% of gasoline, 22% of refined oils, and 62% of fuel-oil. One well, which belongs to the Cuban-American Sugar Company, at Motembo in the Province of Santa Clara, yields ten gallons of 70° Baumé oil daily. Other wells have been drilled in the same region, but the total yield is small. In June, 1918, the United States Geological Survey reported twenty-four companies operating or organized to operate in Cuba.

Haiti and Santo Domingo Island—In the southern part of the island, three miles north of Azua, and on the coast near San Cristobal, ten or fifteen miles west of Santo Domingo, indications of oil have been noted. A well at Azua is reported to have yielded commercial quantities of 20° Baumé oil.

Barbados—For a long period Barbados tar or Manjak, which is used in the manufacture of varnish, has been exported from this island; and petroleum with an asphalt base rich in lubricating oils has been obtained. The wells are shallow. The Lloyd wells at St. Andrew formerly numbered twenty-one. These wells were five feet in diameter, and from eighty to one hundred feet deep, and were lined with pine wood. All yielded oil, and one or two barrels daily could be obtained from each well. Indications of petroleum are numerous, though hitherto little development work has been done.

Trinidad—Trinidad lies near to the coast of Venezuela, and is famous for its asphalt lake, which was named Pitch Lake by Sir Walter Raleigh, who visited it in March, 1595. The Pitch Lake of La Brea is about a mile from the sea, and covers more than one hundred acres. It is of great depth, and in forty years has produced over two million tons of asphalt. The Lake is intersected with streams and rivulets, and is dotted with islands decked with rich tropical vegetation. One very curious feature of the Lake is that the cavities from which the pitch is taken are rapidly refilled, and no estimate is possible of the amount of asphalt in the Lake. The village of La Brea rests on pitch, and there is a constant flow of it to the sea, in a stream fifteen to

eighteen feet deep. Borings have revealed a depth of over 130 feet. It is one of the largest deposits of solid or semi-solid bitumens known. The material as mined consists of about one-third bitumen, one-third sand and one-third water.

One of the best descriptions of the Lake is given by Harry A. Franck, in his book "Roaming Through the West Indies." "It

By Courtesy of Mr. H. A. Franck
CARRYING OFF ASPHALT, PITCH LAKE, TRINIDAD.

is a slightly concave black patch of a hundred acres, with as definite shores as a lake of water, surrounded by a Venezuelan landscape of scanty brush and low, thirsty palms. To the left the black towers of half a dozen oil-wells break the otherwise featureless horizon. About the surface of the hollow several groups of Negroes work leisurely. One in each group turns up with every blow of his pick a black, porous lump of pitch averaging the size of a market-basket; the others bear these

away on their heads to small cars on narrow tracks, along which they are pushed by hand to the 'factory.' A trade wind sweeps almost constantly across the field. The pitch is so light that the largest lump is hardly a burden. From the nature of the case the pace is not fast, and the workers are so constantly in sight that an overseer is hardly needed, nor piece-work required. The holes dug during the day fill imper-

By Courtesy of Mr. H. A. Franck
WASHING DAY, PITCH LAKE, TRINIDAD.

ceptibly and are gone by morning, the deepest one ever excavated having disappeared in three days. Only a small fraction of the field is exploited; it could easily keep all the ships of the world busy. Should it ever be exhausted, there is a still larger deposit just across the bay in Venezuela.

"The lake is soft underfoot, like a tar sidewalk in midsummer, the heels sinking out of sight in a minute or two, and has a faint smell of sulphur. A crease remains around each hole as it refills, some of these rolling under like the edge of a rising mass of

dough, and in these crevices, the rain gathers in puddles of clear, though black-looking water in which the surrounding families do their washing. Most of the pitch goes directly to the steamer, but as it is one-third water, and royalties, duties, and transportation are paid by weight, a certain proportion is boiled in vats in the 'factory' and shipped in barrels constructed on the spot."

Successful oil wells have been drilled on the island, but developments have been seriously hampered by the scarcity of roads and the lack of adequate transportation. "Exudations of oil and asphalt, oil seeps, gas seeps, and mud volcanoes, are on a grand scale."

Fuel oil has now almost entirely supplanted coal for all industrial purposes, according to a report made by Henry D. Baker in 1920, the United States Consul on the island. Deeper drilling is expected to produce a great increase in the yield of petroleum.

The oil obtained from wells near Pitch Lake is dense and is essentially a fuel oil. Others of lighter density, yielding gasoline and kerosene have been discovered, and are refined on the island. The quantity of oil produced in 1921 was 2,354,000 barrels. These figures are illuminating when compared with the total production of 1908, which was 169 barrels.

SOUTH AMERICA

Colombia—There are three districts in Colombia which are regarded as possible petroleum areas. They are the Gulf of Darien, or Urabá section; the West Coast; and the Magdalena River Valley section.

(1) The Gulf of Darien, or Urabá section extends from Puerto Escondido to Puerta Arenas on the coast of the Gulf of Darien, a distance of about forty miles. In this section are to be found many seepages and mud volcanoes, especially towards the headwaters of the Arboletas, San Juan, Vulcan and Mulatos Rivers. The district is unhealthy and difficult of access.

(2) The West Coast district runs from the border of Ecuador on the south, along the eastern slope of the Andes Mountains, in a

TRANSPORTATION IN COLOMBIA.

northeasterly direction. Oil seepages are encountered frequently, and at many widely separated points along the eastern flank of this range. These seepages are to be seen near the headwaters of the San Pedro, near San Vicente on the upper Caguan, west of Florencia near the tributaries of the Caquetá River, and further south near the headwaters of the Aguarica. This country, like the Urabá section, presents many difficulties to the explorer.

(3) The third district where oil indications are to be found is along the right bank of the Magdalena River, extending from near Beltran on the south to the neighborhood of the Barco and Catatumba Rivers. At Tamalameque in the north there are numerous seepages. The most active development in Colombia is on the Magdalena River. Near San Vicente three wells are producing about 3,500 barrels per day, and a number of new holes are being drilled. This district is the most accessible in Colombia.

Venezuela—The richest territory hitherto explored in Venezuela is in the neighborhood of Lake Maracaibo. In 1914 drilling operations were begun at four points, and flowing wells were discovered at each of these places. Mene Grande yielded 13,000 barrels in ten hours, but the World War curtailed drilling development. Tanks were erected, a pipe line built, and a refinery constructed at San Lorenzo, which is about sixty miles south of Lake Maracaibo. A refinery has also been erected in Curaçao. 300,000 barrels of crude petroleum were taken from three of the smaller wells in the Mene Grande region in 1918. In 1919 it was reported by geologists that there are evidences of petroleum over large areas, and samples show that the oil ranges from 15° to 19° Baumé. Clapp lists the occurrences in Lake Maracaibo region as follows:

1. In the district of Mara, near the River Liman, asphalt lake.
2. At Bella Vista, near the city of Maracaibo.
3. In the district of Sucre, on the eastern shore of Lake Maracaibo.
4. On the Sardinate River, extending into Colombia.
5. In the district of Colon, in the State of Zulia, south of Lake Maracaibo.
6. In the Perija field, 50 miles west of Lake Maracaibo.

By Courtesy of Pan American Union

LAKE OF OIL AT RIO DEL ORO, MARACAIBO OIL FIELDS.

The total production of Venezuela in 1921 was 1,078,000 barrels.

Ecuador—The presence of petroleum in Ecuador is men-

tioned as far back as 1700, and pitch was obtained at Santa Elena near the delta of the Guayaquil River. There are promising signs of oil in many parts of the country, and at Santa Paula sufficient oil for local uses is obtained. In 1921 active work was being carried on near Guayaquil.

By Courtesy of Pan American Union

WELL NO. 1 AT TARRA, MARACAIBO OIL FIELDS.

Peru—There is no country in South America so well known for its productive oil fields as Peru. Oil was known to the Incas, who dug brea pits and trenches. They used the oil for waterproofing sheep skins, caulking boats, and in their pottery industries.

By Courtesy of Oil Well Supply Co.

LANDING SUPPLIES IN PERU.

STORAGE TANKS FOR OIL ON PERUVIAN RAILWAY.

The climate of the country is good, despite the fact that it is within the tropics, the heat being moderated by cool breezes. There are parts of Peru where rain never falls; and the water used in drilling for oil is obtained by distillation from sea water. There are many places along the coast where oil is reported, as well as in the interior, near Lake Titicaca; but the productive fields lie between Payta and Tumbes.

NEGRITOS OIL FIELDS, PERU.

There are three companies with a good production in Peru:

1. The International Petroleum Company, owning the fields of *Negritos, Lagunitas and La Brea.*
2. Lobitos Oilfields, Ltd., owning *Lobitos and Restin.*
3. F. G. Piaggio & Company, owning *Zorritos.*

At the end of 1919 there were 940 producing wells, and the average annual production from each well was 444.4 cubic metres. There are two refineries in Peru, one at Talara, and the other at Zorritos. The whole district between Payta and Guayaquil, is petroliferous, and only a tithe of the lands in the northern part of Peru have been developed. The production in 1921 amounted to 3,568,000 barrels which shows a considerable increase on the output for 1920.

Bolivia—Almost all the oil deposits in Bolivia are east of the Andes, and there is a belt of petroleum seepages from central Bolivia into Argentina. Near the city of Santa Cruz oil is taken from pools, which the natives burn in their homes in its crude state, and the city of Santa Cruz uses the oil in the street lamps, from which there is practically no smoke.

It is impossible to get an authentic map of Bolivia, as no complete survey of the country has yet been made, and all maps

YARETA, THE ONLY FUEL IN THE MOUNTAINS OF BOLIVIA.

are especially doubtful in the Beni and Colonias regions, but the territory around Santa Cruz where the principal deposits are found, has been relatively well surveyed. Broadly speaking there are five districts in Bolivia where the indications are good.

1. From Portachuelo north of the City of Santa Cruz to Yacuiba. These are considered the richest oil lands in Bolivia and they include the districts of Porvenir, Lagunillas, La Blanca and Azero. These lands are generally referred to as the Santa Cruz-Chuquisaca-Tarija region.
2. Caupolican, west of Rio Beni.
3. Calacoto, near La Paz.
4. Partially explored lands in the Beni and Upper Santa Cruz.
5. Territorio de Colonias.

Since the collapse a few years ago of the gigantic schemes of Mr. Farquahar in South America, oil companies from the United States have entered the Bolivian fields. During the summer of 1921 two United States companies claimed to have concessions for more than 4,000,000 hectares, and these were in the Santa Cruz-Chuquisaca-Tarija region. In the autumn of 1921 it was reported that these concessions had been purchased by a large oil group in the United States. A British subject has large concessions in the Department of La Paz, covering the provinces of Calacoto, Camacho, Muñecas and Caupolican. This property is reported to have been acquired recently by a British oil company. It is said that the directors of the Madera-Mamoré Railway hold concessions in Bolivian oil lands.

The transportation difficulties in Bolivia are all but insurmountable. The major portion of the oil cannot be conveyed to the Pacific coast, owing to the high mountains that lie between the fields and the sea, so that the oil must either be brought south by pipeline to the nearest navigable water, which is about 600 kilometers from the oil deposits at Santa Cruz, or north through very difficult territory to the Madera-Mamoré Railway and thence to the Amazon.

For the moment it seems only possible to record these districts as reserve oil lands.

Argentina—There are four main centers where oil either has been discovered in paying quantities, or where there are extensive seepages:

1. *Comodoro Rivadavia.* These fields are about 1,000 miles from Buenos Aires. Oil was discovered there in December, 1907, at a depth of 535 metres, when drilling for water. In this district, part of which is owned by the Government of Argentina, there were recently ninety producing wells and fifteen being drilled. There was considerable increase in production during the early part of 1921, due to a gusher, which is the first one in these fields. The oil in this district is heavy, and analysis shows 3.5 per cent. of water. There are several privately owned

companies in Comodoro Rivadavia, with a small production. There are indications of oil near Bahia Blanca and Mar del Plata in the province of Buenos Aires.

2. *Neuquen.* The Government has reserved 20,000 acres at Plaza Huincul, and development is in progress. A number of wells (one a gusher) were brought in last year. The oil is superior in quality to that of Comodoro Rivadavia. Concessions

COMODORO RIVADAVIA.

have been granted to British, American and German interests in Cerro Lotena, Covunco and Challeco.

3. *Salta y Jujuy.* This district is near Bolivia. The seepages are very extensive, but so far the exploratory work has not been successful, owing to the primitive methods adopted.

4. *Cacheuta,* near Mendoza. This petroliferous region lies 9 kilometers south of Kilometer 32, on the Transandine Railroad. There are extensive seepages of petroleum and much asphalt in this neighborhood, but the territory is very badly faulted. Drilling has been carried on here since 1887. Well No. 12 yielded

20 tons of oil a day for eight years; and another well, which flows by heads, and is known as the "Victor Well," yields at present about a ton a day. A Chilean group has obtained a concession of oil land at Cacheuta amounting to about 19,000 hectares. Sixteen kilometers from Mendoza, in a village called Lujan, there is a small refinery which handles 100 tons

DISCOVERY WELL, HARDSTOFT, ENGLAND.

a month, and some of the oil treated in this refinery comes from the "Victor Well." The total production of Argentina in 1921 amounted to 1,747,000 barrels. There are extensive shale deposits both at Cacheuta and Agua Salada. One of these beds shows outcroppings for a distance of seventy-five miles.

EUROPE

Great Britain—Oil has been developed from shale for many years in Scotland, but until recently it was not believed that oil

existed in England in paying quantities. Oil seeps, bitumens and pitch are found at many places in Great Britain. A variety of bitumen called "mineral India rubber," because of its elastic properties, was found at an early date in Derbyshire, and was named "elaterite" by Hausmann. Natural gas is found in many places. The discovery well is on a faulted dome, at Hardstoft in Derbyshire, and has been flowing since June, 1919, at the rate of 12 barrels daily. The oil is particularly rich in high grade lubricants, and its specific gravity is 0.823. The industry is still in the experimental stage, and unless results are more satisfactory it may prove abortive. The production in Great Britain in 1921 amounted to 2,652 barrels.

France—The shale deposits of France are of some importance, and the well-known asphalt of the Val de Travers occurs in the Department of Aisne. In lower Alsace, which is now included in France, a good production of oil has been obtained since 1880. It is noteworthy that the Pechelbron Field, nine miles north of Hagenau, has been worked on a commercial scale since 1742. The gravity of the oil is from 25° to 29° Baumé. The most recent reports show plans for the exploitation of Ardêche, Gard, Isère, Jura and Haute Savoie. The production in France in 1921 amounted to 392,000 barrels.

Germany—There are a number of oil fields in Germany which produce a small quantity of heavy petroleum. The North German oil field is a belt lying between the Weser and the Elbe, and includes Wietze, Steinförde, Oelheim, and other pools of Hanover. Oil struck at shallow depths is heavy, but at greater depths lighter oil is obtained. The wells are rarely of great capacity, though long-lived, and flowing wells are infrequent. An asphalt deposit occurs between Limmer and Harenberg, and another at Vorwohle, on the southwest slope of Hils Mountain. Since the armistice, investigators in Germany have been working upon the extraction of oil from shale. The production in Germany in 1921 amounted to 200,000 barrels.

Italy and Sicily—Indications of petroleum are spread over a wide area in Italy, and three small fields have been developed:

The *Emilia fields* in northern Italy, which lie almost parallel with the River Po, and to the south of it; the *Chieti field,* near the center of Italy and close to the Adriatic Sea; and the *Liris Valley fields,* between Rome and Naples.

In October, 1917, in the "Journal de Pétrole," there was published an article dealing with the petroleum industry of Italy. The writer says: "The prevalent opinion that Italy is poorly endowed with petroleum is today contradicted by a number of natural phenomena, which indicate the existence of the valuable liquid in numerous localities: Parma, Piacenza, Tuscany, Bologna, Rome, Calabria, Catania, Palermo, the Lipari Islands, etc."

Girgenti (Agrigentum) in Sicily is interesting, because Strabo, Pliny, and other authors mention the use of Sicilian oil from Agrigentum for illuminating purposes.

The most valuable deposits of oil and asphalt in Sicily lie in the region of Ragusa, Modica, and the Val di Noto. Some of the vesicles of the basaltic lava from Etna are filled with petroleum and others with crystalline paraffin. The production of oil in Italy during 1921 amounted to 35,000 barrels.

Rumania—In Rumania may be seen the most primitive and the most modern methods of obtaining oil in the same neighborhood. The peasant, long prior to the scientific method of drilling, obtained from his hand-dug well supplies of petroleum rich in illuminants; and, owing to the present demand, he is encouraged to pursue his crude methods of extracting petroleum.

Rumania has produced petroleum since 1857, which is two years before Drake discovered oil in the United States; and prior to the war it was the second largest producing country in Europe. The first field that aroused interest in Rumania was at Bustenari, the oil from which is similar to that of Franklin, Pennsylvania. The next field was discovered in Campina, which yields a paraffin base oil, and lies west of Bustenari. The oil is found in Campina comparatively near the surface. "The color of Rumanian crude is of various shades of brown. Its specific

gravity varies considerably, not only in the same field but in the same well."

Dambovitza, Buzeu, Moreni, Bana-Moreni, Filipesti de Padure and Baicoi are among the newer fields which have yielded results justifying the expectations that there were great resources of oil awaiting development in Rumania. In most of the fields there are from three to six strata where oil is obtained. There

By Courtesy of Oil Well Supply Co.
HAND-DUG WELLS IN RUMANIA.

is a light railway from Baicoi through Filipesti de Padure to Moreni connecting these two important fields. They are equipped with electric current, which is supplied from Campina. The Baicoi fields have an initial production of from 500 to 2,500 barrels per day, and the oil is similar to that of Bustenari. Mud volcanoes and oil seeps are found at Berca and Beciu, twelve miles from the city of Buzeu.

Drilling in Rumania is difficult owing to the high angle of

inclination of the strata, which tends to deflect the boring tools. The chief refineries in Rumania are at Ploesti. To this town there is a system of pipe lines from all the important oil fields. A pipe line has been completed to Constanzia, on the Black Sea, which is about 170 miles from the principal areas of production.

An analysis of the oil from Moreni and Baicoi is given in a book written by Guttentag in 1918, which shows the approximate compositions in commercial products of these two Rumanian crude oils:

By Courtesy of Oil Well Supply Co.

MORENI, RUMANIA.

	Moreni	*Baicoi*
Light Benzine	35.38%	4.28%
Heavy Benzine	9.29	15.68
Kerosene	14.99	27.75
Gas Oil	8.17	10.27
Fuel Oil	31.01	41.07

Prior to the defeat of the Rumanians by the Germans in December, 1916, many of the oil wells were destroyed by command of the Allied authorities. This was carried out in the closing days of November, and consisted in plug-

ging the wells and wrecking surface equipment. In August, 1917, it was reported that the uncorking of the wells had been performed with such skill that the production was nearly 50% of the average daily output in 1915. Since the armistice the operating companies have been busily engaged in drilling new wells and in restoring the flow of bore holes.

Ploesti is the center of the refining industry, and there are approximately forty refineries in Rumania. The total production of Rumania in 1921 was 8,347,000 barrels. Prior to the war Rumania produced about 12,000,000 barrels annually.

Bukowina and Transylvania are regarded by geologists as amongst the most promising districts in Southeastern Europe where little development work has taken place.

Galicia—The principal oil fields of Galicia, Rumania and Russia are in minor folds that are connected generically with the Carpathian and Caucasian ranges. The Galician oil belt extends along the northern slope of the Carpathian Mountains. Galicia, which formed part of the Austro-Hungarian Empire prior to 1914, is divided into two parts, and the fields are designated "East Galicia" and "West Galicia," the former being the more productive.

As "earth balsam" Galician petroleum was known in 1506, and in local records, references occur in the seventeenth century. In 1853 Galician petroleum replaced candles on the Emperor Ferdinand's North Railway.

The peak of production of these fields was reached in 1909, when Galicia yielded 14,932,799 barrels of oil. Since that date there has been a steady decline; but no important field in Europe has been less thoroughly investigated than that of Galicia.

East Galicia. The richest district in East Galicia is the Boryslav-Tustanowice. Here are to be found some of the deepest wells in the world, many of them being between five and six thousand feet. The fields lie between the valleys of the Dneister and Stryj, near the Carpathians. In the western part of the field the oil is heavy, viscous and very dark. In the east it is lighter in gravity and color, and is rich in benzine. These fields

extend into western Ukraine. The most valuable ozokerite in the world occurs in these fields, and is found in very large quantities. Ozokerite is a native bitumen with a paraffin base. It is essentially paraffin, and is supposed to be formed by the drying up of paraffin oil. The chief of the minor fields are Bitkow, Opaka-Schodnica-Urycz and Mraznica.

West Galicia. The Western Galician oil fields have received increased attention since 1912, and give good results in the districts of Bobrka, Potok and Gorlice. On an anticline at Potok, gushers of high grade light gravity oil have been found. The

TEMPLE OF ETERNAL FIRE, BAKU, RUSSIA.

Kleczany field in the Gorlice district yields amber-colored oil, and is profitable with an exceedingly small production.

Some of the earlier Galician fields were abandoned at the close of the last century, but during recent years wells have been reopened and good production obtained. The total production of East and West Galicia in 1921 was 3,665,000 barrels.

Russia—In 1901 Russia produced 85,168,556 barrels of oil, or more than half the world's production. Since that year the yield from Russian fields has declined. Petroleum has been known to exist in Baku for countless ages, and pilgrimages dur-

ing many centuries have been made to this field by Fire-worshipers. Hordes of Parsees have come from the East to the ancient temples dedicated to the eternal power of mysterious fire, lighted no man knew how. Baku was visited annually by thousands of pilgrims prior to the Saracenic conquest of 676;

TANK CARS USED FOR FORWARDING KEROSENE FROM BAKU TO BATOUM, PRIOR TO CONSTRUCTION OF PIPE LINE.

and the United States Consular Report of 1880 states that the temple of Surakhani was visited by priests in 1879. Baku was annexed from Persia in 1727, by Peter the Great, who was aware of the value of petroleum, and made arrangements for its transportation up the Volga. Later the district was restored to Persia, but the petroleum deposits were not worked until its reannexation by Russia in 1806.

In the first records of Fire-worship, the "eternal fire" of Baku finds mention. Baku is an old Tatar city on the Caspian Sea, and in modern times has attained world-wide fame owing to the great yield of its gushers. The oil is heavy and accompanied by much gas. The main outlet for the production of Baku has been the Caspian Sea and the River Volga. In 1905 an 8-inch pipeline from Baku to Batoum, on the Black Sea, was completed. It

By Courtesy of Oil Well Supply Co.
BALAKHANI OIL FIELD, RUSSIA.

runs parallel to the railway, and is 560 miles long, affording an outlet to the main ocean highways for Russian oils. The territory fringing the Caspian Sea is regarded by some as a colossal subterranean reservoir, rivalling the richest oil territory in the world. Oil is measured in Russia in poods, and 8.33 poods of crude oil is equal to one United States barrel of 42 gallons.

Oil is found in many parts of Russia, but the main fields are around the Caspian Sea:

1. *Baku.* The largest producing fields in Russia are near Baku. There are two main areas:

(*a*) BALAKHANI-SABUNTCHI-ROMANI. These fields lie northeast of Baku. The mud volcano, Bog-Boga, is one of the highest points of this region. These fields håve borne the name of the three villages, although they have long since merged into one continuous field, covering a little more than 2,000 acres. In the neighborhood of these three fields are two minor fields; *Su-*

By Courtesy of Oil Well Supply Co.
BIBI-EIBAT OIL FIELD, RUSSIA.

rakhani, southeast of Sabuntchi, and *Binagadi,* five miles northwest of Balakhani. Surakhani has been known since the days of the Fire-worshipers as a gas field, and the famous temple of India's devotees stands there. Nearly all the wells drilled below 1,400 feet are gushers. From the district around these five villages has come a large proportion of the oil obtained from Russia.

(*b*) BIBI-EIBAT. This is the most productive field per acre in the world; it lies three miles south of Baku, and has an area of

about 1,000 acres. Oil and gas seeps mark the surface, and mud volcanoes are found near the field. The Bibi-Eibat field in 1912 had yielded 280,500,000 barrels of oil, an average of about 280,000 barrels per acre. According to A. Beeby Thompson, Plot 19 Bibi-Eibat, with an area of 27 acres, has yielded about 9,000,000 tons of oil.

2. *Grosni and Maikop.* After the Baku Fields, the most famous are the Grosni, which in 1917 produced about 15,000,000

By Courtesy of Oil Well Supply Co.

APSHERON OIL FIELD, CASPIAN SEA.

barrels, or nearly one-third of the amount yielded by the Baku wells for the same year.

The Maikop field came into prominence first during the oil boom in London in 1910. This field was responsible for the formation of many still-born companies. It was opened in 1911, with a small production, but development was interrupted by the war. The sands, when they outcrop, are impregnated with oil, so that, when squeezed by hand, the oil oozes out like water from a sponge. Many rivers in this region carry oil films on the surface.

3. *Kertch and Taman.* Kertch and Taman are situated in the Crimean district, between the Black Sea and the Sea of Azov. The ridges in this region are marked by volcanoes, carrying oily mud.

4. *Sviatoi and Cheleken.* Sviatoi, or Holy Island, lies in the Caspian, off the Apsheron Peninsula, about thirty miles from Baku. This field contains enormous deposits of pitch, and the oil has a gravity of 0.92 to 0.94.

On Cheleken Island ozokerite is found in faults, by which they are sealed. The petroleum from the Island is rich in paraffin, and the wells have been highly productive.

5. *Neftianoia Gora (Naphtha Hill).* The mainland east of the Caspian Sea contains a rich petroliferous land. On Naphtha Hill, which lies about 100 miles from Krasnovodsk, are found on the surface, petroleum, sand and ozokerite; mud volcanoes exist there and continually throw out mud, petroleum and ozokerite. Abandoned wells show where petroleum was collected in ancient times.

6. *Ural-Caspian Oil Fields.* North of the Caspian Sea and inland from the port of Guriev, lie what are known as the Ural-Caspian Oil Fields, which yield oil of high grade in large quantities. The climate is one of extremes, and this in conjunction with transportation difficulties has retarded development.

In addition to these well-known fields, there are other districts where there is either a good production of oil, or promising indications. Between Baku and Batoum, and near the city of Tiflis, lies a district which yields oil. In the Ferghana district, about 400 miles east of Bokhara, nearly a quarter million barrels of oil are produced annually. The territory between Turkestan and Sakhalin Island has not been thoroughly explored; but in the neighborhood of Lake Baikal and on Sakhalin Island there are rich deposits of petroleum. In northern Russia, about 400 miles southeast of Archangel, oil containing over 40% of kerosene has been discovered.

Until a few years ago, the chief source from which oil suitable for fuel could be obtained was Russia, and the bulk of this was

consumed in pre-revolution days in the country itself, chiefly in the steamers on the Caspian Sea, and on the Trans-Caucasian Railway, the Mid-Asiatic, Tashkent, and other railways, and in a few industrial plants.

When Russia's production was at its height, it is important to remember that this was mainly obtained from a district containing less than 4,000 acres.

There are few countries in the world where undeveloped resources of all kinds are so great as in Russia, and the potential production of petroleum of this vast territory is incalculable. The estimated production of Russia in 1921 was 28,500,000 barrels.

ASIA

Mesopotamia or Irak—During recent years it has become clear that there are extensive undeveloped petroleum resources in Asia. Oil has been known to exist around the Caspian Sea for countless ages. In a letter to the writer, the late Dr. Morris Jastrow, of the University of Pennsylvania, said "bitumen was very largely used in ancient Babylonia in building, as well as in the inlaying of statues." He added, "We have also found in Babylonian inscriptions the word 'napta,' which seems to be the original of our 'naphtha,' which was employed from very ancient days (circa 3000 B. C.) down to the latest period." Herodotus tells us of bitumen found in the River Hit in the Euphrates valley.

Mesopotamia, or Irak, has been the subject of dispute and diplomatic notes between several of the great powers, mainly because it promises to be a large producer of oil. During the war, in addition to the armies, large bodies of men were employed in examining the prospects for petroleum, and the very favorable reports of these experts led to a realization of the importance of the valleys of the lower Euphrates and Tigris Rivers. A small native industry has been established.

Persia—Persia was known to contain oil long before the Christian era, and for centuries certain springs have been

worked with comparative success; but not until the exploratory work of Mr. G. C. d'Arcy had been completed was any attempt made to obtain oil by modern methods. Mr. d'Arcy's pioneer work in a sterile country, beneath a blistering sun, with repeated disappointments, and its ultimate success, is one of the many romances connected with the quest of oil.

The Persian oil fields are situated in very forbidding territory and remote from the Persian Gulf; but the modern oil man is inured to trials and difficulties, and a pipeline has been laid from the fields to the coast, where the oil obtained in the sun-scorched hinterland is refined and shipped. The first refinery was built eight years ago; the oil is rich in kerosene, and one well is reported to have yielded over 100,000 tons of oil. The production of Persia is greater than that of India, and ultimately development work will extend into the more inaccessible parts of the country, where unmistakable evidences of oil are found. The oil is of an exceptionally high grade, and claimed to be superior to the average of oils produced on the American continent. It contains a large percentage of gasoline and kerosene of high quality, excellent lubricating oils, fuel oils of high thermal utility, and a good percentage of first grade paraffin.

Development on a modern scale began in 1903, and later near Schustar a well 1,100 feet deep came in, and oil spouted 70 feet high, carrying away the derrick. In 1920 it was said wells had already been drilled capable of yielding five million tons annually. The fields lie in the north, west and south. There are five main areas:

1. Schustar
2. Ahwaz
3. Tchiah Sourlch
4. Daliki
5. Qishm

In the Schustar district, 45% of lubricating oil is obtained, and at Tchiah Sourlch 57.6% of kerosene. The production of Persia in 1921 amounted to 14,600,000 barrels.

British India—Near Sibi on the Quetta Railway in Baluchistan, petroleum exists almost as dense as water, containing a

large proportion of asphaltum; and oil deposits are also found in the Punjab at Mogalkot, and in Assam. These latter fields have greatly increased since 1904, but the largest sources of petroleum in British India hitherto discovered are found in Burmah. For centuries oil has been obtained here by the most primitive methods, and these wells are regarded by some as the

By Courtesy of National Supply Companies
ELEPHANT MOVING BIG TIMBER IN INDIA.

oldest in the world. It may be interesting to recall the observations of a traveler in regard to the way in which oil was obtained. The book, in which the following extract appears, was published in 1826: "Walking to the nearest well, we found the aperture about four feet square, and the sides lined, as far as we could see down, with timber. The oil is drawn up in an iron pot fastened to a rope passed over a wooden cylinder, which revolves on an axis supported by two upright posts. When the

pot is filled, two men take hold of the rope by the end and run down a declivity which is cut in the ground, to a distance equivalent to the depth of the well. Thus, when they reach the end of the track, the pot is raised to its proper elevation; the contents, water and oil together, are then discharged into a cistern, and the water is afterwards drawn through a hole in the bottom."

By Courtesy of Oil Well Supply Co.
BURMAH OIL FIELD, BRITISH INDIA.

East of the Irawadi, and about 300 miles from Rangoon, lies the district of the Yenangyaung ("Oil Creek"). Here the Burmah Oil Company has been successful in obtaining a very large production of oil, which varies greatly in quality, some containing no paraffin, while other wells are very rich in paraffin. Large refineries have been built near Rangoon.

Singu and Yenangyat, which are near the Irawadi and southwest of Mandalay, also yield oil in abundance.

Several islands in the Arakan group, which lie due north of the Andaman Islands near the coast of Burmah, give an oil which is like brandy in color, and in its crude state can be burned in lamps.

The production of India during 1921 amounted to 6,864,000 barrels.

China—Petroleum and natural gas have been used in China from remote ages, but recent research for oil in the country has not been rewarded with success. Shortly before the World War, an important concession was granted by the Chinese Government to a large oil company providing for the testing, and if approved, the subsequent working of the oil deposits believed to exist in Yengchang, Yenanfu, and the neighboring fields of Shensi, and Chentehfu and the adjoining fields of Chihli. It was reported in 1917 that the company had abandoned the enterprise. The failure to obtain oil has been a considerable surprise, as some wells in the district were producing until a few years ago.

Japan and Formosa—The presence of oil in Japan has been known for centuries, and the Japanese, adopting the most primitive methods, collected it for many years. Japanese history says that "rock oil" ("burning water") was first discovered and used in the Echigo district about 615 A. D. A quarter of a century ago the American method of drilling was introduced and large Japanese companies formed, which are now engaged in producing and refining oil. Several flowing wells have been struck; some of these have furnished large quantities of oil. One well drilled in 1914 gave a production of over 10,000 barrels a day. The oil is of a heavy grade. In December, 1919, a new pool was discovered by the Hoden Oil Company at Hanegawa in the Youri district of the Akita prefecture. The principal deposits are on the island of Honshiu; but oil has been discovered in Hokkaido and Formosa. The main fields are in the following prefectures: Niigata, Akita, Hokkaido, Shizuoka, Yamagata, and Nagano. In Formosa "wild-cat" tests drilled by the Hoden Oil Company, resulted in the discovery of petroleum at Shichiku testing 29° Baumé gravity, at a depth of about

900 feet. The unit of measurement in Japan is called koku, and one koku equals 1.136 barrels. The production of Japan and Formosa in 1921 amounted to 2,600,000 barrels.

Philippine Islands—The Philippine Islands form an archipelago in the Malay group, and lie between Borneo and Formosa, both of which produce oil. Seeps and residues of

WELL IN JAPANESE OIL FIELD.

petroleum and inflammable gas are found on many islands of the group. Little development work has taken place, but the oil seeps are numerous, some of which yield petroleum having a gravity of 28° to 30° Baumé. The principal islands where seepages are found are:

Luzon	Cebu
Mindoro	Leyte
Panay	

DUTCH EAST INDIES

Borneo—Several islands included in the Dutch East Indies have recently come into marked prominence in the production

of oil. The Royal Dutch and associated companies have been mainly responsible for this development. Borneo, the largest of the islands, has been for the past twenty years very successfully exploited. The main developments have been in the south-eastern portion of the island, but there are numerous seepages in Northern Borneo and the island of Labuan. The island of Tarakan has developed into a very important field. Sarawak, a British province, yielded 1,015,949 barrels in 1920.

Sumatra—The first concession of oil-bearing territory on the island of Sumatra was granted in 1883, which was later acquired by the Royal Dutch Company. Extensive fields exist on the northeast coast. The oil has an unusually high proportion of the more volatile hydrocarbons, evolving inflammable gas in the cold. Oil is also reported in the Kingdom of Siak, and there is a large oil field in Palembang. In 1917, at Pangalam, a well which yielded 1,200 tons of light gravity oil was drilled.

Java—Oil is widely disseminated through Java. The principal field extends from Samarang through Rembang and Surabaya to Madoera Island, and the smaller islands east of it. The crude oil has a density ranging from 23° to 40° Baumé, and contains considerable asphalt and a large proportion of paraffin. The islands of the Dutch East Indies have had great success in the oil development of recent years, and the industry is rapidly expanding. The total production in the Dutch East Indies during 1921, exclusive of Sarawak, amounted to 18,000,000 barrels.

AFRICA

Egypt—Up to the present time Africa has not justified expectations; neither Nigeria nor South Africa has rewarded the prospector for oil. Shales have been found in the Tao, but the most successful fields have been discovered in Egypt and Algeria.

The oil fields in Egypt lie along the west coast of the Gulf of Suez, northeast of the Red Sea Hills. They are the most prolific fields on the continent of Africa. The main fields are the Jemsa and Zeit, and the Hurghada, west of Jifatin Island. The

oil from the Hurghada field is transported to Suez, where the Royal Dutch Company has erected a large refinery. There are tank storage facilities both at Jemsa and Hurghada, as well as at Suez.

The Egyptian State Railway Department is preparing to drill for oil near Abu Dirba, and to construct a refinery at Suez.

The oil industry of Egypt and the Soudan is especially important, since Egypt suffers from the lack of adequate fuel supplies, and the discovery of rich fields of oil would be a great incentive to commercial development. The production of Egypt in 1921 amounted to 1,181,000 barrels.

Algeria—A deposit of heavy oil is being worked in Algeria under the direction of the French. An article published during October, 1917, in the "Journal de Pétrole," says: "In the Département D'Oran, the principal indications of hydrocarbons are found in the three regions of Dahra, Tilouanet, and Bel-Hacel." The production of Algeria in 1921 amounted to 3,000 barrels.

AUSTRALASIA

Papua—The indications are said to be favorable for the establishing of an oil industry in Papua, and prospective work has been carried on for many years. Papua is regarded as a more hopeful field than either Australia or New Zealand. Indications of petroleum are good over an area of 2,000 square miles, and the quality of the oil is of very high grade.

Australia—Traces of petroleum occur in several parts of Australia, more particularly at Yorktown and Narrabeen, near Sydney. Exudes are also found near the mouths of the Warren and Donnelly Rivers. There is great interest in the search for petroleum in Australia, but the success has not so far harmonized with expectations.

New Zealand—Many reports have been published on the petroleum deposits of New Zealand, which were tested at Taranaki and Kotuku. The petroleum industry in New Zealand was in 1917 restricted to the operations of the "Taranaki Oil Wells, Ltd.," which controls a few deep oil wells of small capacity, and a petroleum refinery at Taranaki, North Island.

SUPPLEMENTARY DATA

PAN AMERICAN PETROLEUM & TRANSPORT COMPANY
(Incorporated Feb. 2, 1916)

CAPITAL STOCK, OUTSTANDING:

Common	$50,077,450.00
Common—(Class B)	20,099,250.00
Total	$70,176,700.00

ASSETS:

The principal Capital Assets of the Pan American Petroleum & Transport Company are:

31 tankers—deadweight capacity 272,493 tons.

Oil properties situated in the State of California (held by its wholly owned company, the Pan American Petroleum Company).

Stocks of controlled or affiliated companies (percentage of stock held to total stock outstanding shown in parentheses)—

$ 9,035,000	Mexican Petroleum Co. Ltd., of Delaware, pfd.	(75.29%)
$31,461,000	Mexican Petroleum Co. Ltd., of Delaware, com.	(72.88%)
$ 328,472	The Caloric Company Preferred	(82.12%)
$ 619,928	The Caloric Company Common	(71.92%)
£ 1,500,000	British Mexican Petroleum Company Limited capital stock	(50%)

The Caloric Company has storage and distributing facilities at the following ports in Brazil:

Pará
Bahia
Pernambuco
Rio de Janeiro
Santos

OFFICERS

E. L. Doheny,	*President*
Herbert G. Wylie,	*Vice-President and General Manager*
Charles E. Harwood,	*Vice-President*
Norman Bridge,	*Vice-President*
J. M. Danziger,	*Vice-President*
Paul H. Harwood,	*Vice-President*
J. S. Wood,	*Vice-President*
E. L. Doheny, Jr.,	*Vice-President and Treasurer*
O. D. Bennett,	*Secretary*
A. R. Pointer,	*Comptroller*
R. M. Sands,	*Assistant Sec'y and Assistant Treas.*
A. N. Penn,	*Assistant Treasurer*

DIRECTORS

Class of 1922	*Class of 1923*	*Class of 1924*
E. L. Doheny	Norman Bridge	Jacques Weinberger
Herbert G. Wylie	C. E. Doheny	Charles E. Harwood
J. M. Danziger	E. R. Tinker, Jr.	Paul H. Harwood
E. L. Doheny, Jr.	O. D. Bennett	S. W. Chambers
R. M. Sands	Elisha Walker	Harold Walker

MEXICAN PETROLEUM COMPANY, LIMITED, OF DELAWARE
(Incorporated February 16, 1907)

CAPITAL STOCK, OUTSTANDING:

431,657 shares common stock of $100 each	$43,165,700.00
120,000 shares non-cumulative preferred stock of $100 each	12,000,000.00
Total	$55,165,700.00

ASSETS:

The principal Capital Assets of the Company are represented by stock holdings in subsidiary companies which are enumerated below, together with the respective percentages of stock held to the total stock outstanding:

Mexican Petroleum Company (California)	98.99%
Huasteca Petroleum Company	100.00%
Mexican Petroleum Corporation	100.00%
Mexican Petroleum Corporation of Louisiana, Inc.	100.00%

The principal Capital Assets owned by the foregoing subsidiaries are:

1,400,000 acres of land in Mexico.

Oil production, storage (8,356,000 barrels) and handling facilities in Mexico.

Refineries in Mexico and the United States.

Storage stations (5,366,038 barrels) together with distributing facilities at the following points:

Portland, Maine
Boston, Massachusetts
Fall River, Massachusetts
Providence, Rhode Island
Carteret, Port of New York
Passaic, Port of New York
Baltimore, Maryland
Norfolk, Virginia
Jacksonville, Florida
Tampa, Florida
Destrehan, Louisiana
Southport, Louisiana
New Orleans, Louisiana
Franklin, Louisiana
Galveston, Texas
Cristobal, Canal Zone
Montevideo, Uruguay
Buenos Aires, Argentina.

OFFICERS

E. L. Doheny,	*President*
Herbert G. Wylie,	*Vice-President and General Manager*
Charles E. Harwood,	*Vice-President*
Norman Bridge,	*Vice-President*
J. M. Danziger,	*Vice-President*
J. S. Wood,	*Vice-President*
E. L. Doheny, Jr.,	*Vice-President and Treasurer*
O. D. Bennett,	*Secretary*
A. R. Pointer,	*Comptroller*
R. M. Sands,	*Assistant Sec'y and Assistant Treas.*
A. N. Penn,	*Assistant Treasurer*

DIRECTORS

Class of 1922	*Class of 1923*	*Class of 1924*
Charles E. Harwood	Norman Bridge	E. L. Doheny
S. M. Spalding	S. W. Chambers	C. E. Doheny
R. M. Sands	E. L. Doheny, Jr.	Herbert G. Wylie
J. S. Wood	O. D. Bennett	J. M. Danziger
		Paul H. Harwood

BRITISH MEXICAN PETROLEUM COMPANY, LIMITED

(Incorporated July 15, 1919)

ISSUED CAPITAL:

£2,000,000 Series "A"

£1,000,000 Series "B"

(50% of above is owned by the Pan American Petroleum & Transport Company.)

PRINCIPAL CAPITAL ASSETS:

7 Tankers with a total deadweight tonnage of 65,515.

790,000 barrels of oil storage, at the following stations:

Southampton
Avonmouth
Liverpool
South Shields
Glasgow

and storage accommodation at Thames Haven.

DIRECTORS

THE RT. HON. VISCOUNT PIRRIE, P. C.
WILLIAM WEIR
SIR THOMAS ROYDEN, BART.
SIR PETER MCCLELLAND, K. B. E.
JAMES B. R. MORTON
SIR JAMES T. CURRIE, K. C. B.
E. L. DOHENY
HERBERT G. WYLIE
E. L. DOHENY, JR.
ELISHA WALKER
L. P. SHELDON
SIR ALEXANDER MAGUIRE

DISTRIBUTING STATIONS

MEXICAN PETROLEUM CORPORATION

Terminal	Tanks	Total Storage Barrels	Acreage	Date of Acquisition of Property
Portland, Maine	7	365,500	57.1	1915
Boston, Mass.	6	330,000	24.895	1916
Fall River, Mass., No. 1	1	55,000	4.107	1919
Fall River, Mass., No. 2			5.97	1919
Providence, R. I.				
(Allens Ave.)	2	92,500	7.767	1915
(Kettle Point)	4	220,000	40.71	1915
Carteret, Port of New York	8	440,000	337.12	1915
Passaic, Port of New York	2	110,000	6.22	1919
Baltimore, Md.	8	440,000	86.39	1919
Norfolk, Va.	8	403,500	79.26	1917
Jacksonville, Fla.	3	165,000	16.8	1916
Tampa, Fla.	3	165,000	22.132	1915
Galveston, Texas				
(East End)	6	330,000	38.479	1919
(West End)	3	165,000	6.41	1919
Cristobal, Canal Zone	3	165,000	6.2	1915
Montevideo, Uruguay	1	55,000	.91	1919
Buenos Aires, Argentina	3	165,000	7.94	1919 and 1921

MEXICAN PETROLEUM CORPORATION OF LOUISIANA, INC.

Terminal	Tanks	Total Storage Barrels	Acreage	Date of Acquisition of Property
Destrehan, La. (Refinery)	79	1,525,538	1,050.5	1914
New Orleans, La.				
(City Storage)	1	10,000	3.17	1917
(Southport)	2	110,000	10.	1919
Franklin, La.	1	55,000	5.76	1919

THE CALORIC COMPANY

Terminal	Tanks	Total Storage Barrels	Acreage	Date of Acquisition of Property
Pará, Brazil	1	55,000		
Pernambuco, Brazil	2	65,000	1.59	1918
Bahia, Brazil	1	55,000	.62	1915
Rio de Janeiro, Brazil	4	140,000	4.99	1918 and 1921
Santos, Brazil	1	55,000		

BRITISH MEXICAN PETROLEUM COMPANY, LIMITED

Terminal	Tanks	Total Storage Barrels	Acreage	Date of Acquisition of Property
Avonmouth, England	2	110,000	5.	1920
Ellesmere Port (Manchester ship Canal) England			64.	1919
Glasgow, Scotland	3	135,000	64.	1919
Liverpool, England	4	190,000	7.75	1919
Southampton, England	5	245,000	7.	1919
South Shields, England	5	110,000	1.9	1919

UNITED STATES GEOLOGICAL SURVEY
World Production of Petroleum

Country	Production, 1920			Total Production, 1857–1920		
	Barrels of 42 U. S. Gallons	Metric Tons	Percentage of Total by Volume	Barrels of 42 U. S. Gallons	Metric Tons	Percentage of Total by Volume
United States	443,402,000 [1]	62,188,000	63.8	5,429,693,000	729,640,000	62.1
Mexico	163,540,000 [2]	24,410,000	23.5	536,524,000	80,047,000	6.1
Russia	25,429,600 [3]	3,471,130	3.6	1,904,021,000	252,072,000	21.8
Dutch East Indies	17,529,210	2,365,347 [4]	2.5	219,584,000	29,690,000	2.5
Persia[5]	12,352,655	1,685,219	1.8	48,070,000 [22]	6,558,000	.5
India[6]	7,500,000	1,000,000	1.1	122,583,000	16,343,000	1.4
Rumania	7,435,344	1,034,123 [7]	1.1	165,462,000	23,013,000	1.9
Poland (Galicia)	5,606,116	764,818 [8]	.8	171,263,000	23,700,000	2.0
Peru[9]	2,816,649	373,280	.4	29,797,000	3,968,000	
Japan and Formosa	2,139,777 [10]	285,076	.3	42,810,000	5,708,000	
Trinidad	2,083,027 [11]	289,712	.3	11,356,000	1,580,000	
Argentina	1,665,989	242,502 [12]	.2	7,225,000	1,043,000	
Egypt[13]	1,042,000	152,120	.2	6,990,000 [22]	1,017,000	
British Borneo (Sarawak)[14]	1,015,949	146,285	.2	4,052,000	584,000	
Venezuela	456,996	69,539 [15]		1,335,000	203,000	1.7
France (Alsace)	388,700	54,900 [16]		723,000 [23]	102,000	
Germany	212,046	29,950 [17]		17,120,000	2,318,000	
Canada	196,937 [18]	26,258	.2	24,864,000	3,315,000	
Italy	34,180	4,750 [19]		1,042,000	148,000	
Algeria	3,916	609 [20]		37,000	6,000	
England[21]	2,909	382		5,000	56,000	
Other	....	....		416,000		
	694,854,000	98,594,000	100.0	8,744,972,000	1,181,111,000	100.0

[1]U. S. Geological Survey (preliminary).
[2]Department of Industry, Commerce and Labor, Mexico (preliminary).
[3]Soviet records translated by Russian division, Bureau of Foreign and Domestic Commerce, Commerce Report 164, p. 286.
[4]Bureau of Mines, Dutch East Indies.
[5]Imperial Mineral Resources Bureau Statistical Summary (London), 1913–1920.
[6]Estimated by Imperial Mineral Resources Bureau (London).
[7]Moniteur du pétrole roumain, February 15, 1921.
[8]Przeglad Naftowy, Rok 1, No. 1, p. 15, March, 1921.
[9]Cuerpo de ingenieros de minas del Peru.
[10]Economic Review, April 29, 1921.
[11]Mines Department, Trinidad.
[12]Director General of Mines, Geology and Hydrology, Buenos Aires.
[13]Minister of Finance, Cairo.
[14]Imperial Mineral Resources Bureau Statistical Summary (London), 1913–1920.
[15]Memoria del ministerio del fomento.
[16]Imperial Institute, London.
[17]Consular Report.
[18]Department of Mines, Ottawa (preliminary report).
[19]Minister of Agriculture, Rome.
[20]Consular Report.
[21]H. M. Petroleum Executive, London.
[22]1913–1920, inclusive.
[23]1919 and 1920.

OIL MEASUREMENT TABLE

Baumé Gravity	Specific Gravity	Lbs. per Gallon	Lbs. per Imp. Gallon	Gallons per Lb.	Imp. Gallons per Lb.	Lbs. per Barrel	Barrels per Long Ton (2240 Lbs.)	Barrels per Metric Ton (2204.6223 Lbs.)	Barrels per Short Ton (2000 Lbs.)
10.	1.0000	8.328	10.	.1201	.1000	349.776	6.404	6.303	5.718
10.5	.9964	8.298	9.964	.1205	.1004	348.516	6.427	6.326	5.739
11.	.9929	8.269	9.929	.1209	.1007	347.298	6.450	6.348	5.759
11.5	.9894	8.240	9.894	.1214	.1011	346.080	6.472	6.370	5.779
12.	.9859	8.211	9.859	.1218	.1014	344.862	6.495	6.393	5.799
12.5	.9825	8.182	9.825	.1222	.1018	343.644	6.518	6.415	5.820
13.	.9790	8.153	9.790	.1227	.1021	342.426	6.542	6.438	5.841
13.5	.9756	8.125	9.756	.1231	.1025	341.250	6.564	6.460	5.861
14.	.9722	8.097	9.722	.1235	.1029	340.074	6.587	6.483	5.881
14.5	.9689	8.069	9.689	.1239	.1032	338.898	6.610	6.505	5.901
15.	.9655	8.041	9.655	.1244	.1036	337.722	6.633	6.528	5.922
15.5	.9622	8.013	9.622	.1248	.1039	336.546	6.656	6.551	5.943
16.	.9589	7.986	9.589	.1252	.1043	335.412	6.678	6.573	5.963
16.5	.9556	7.958	9.556	.1257	.1046	334.236	6.702	6.596	5.984
17.	.9524	7.932	9.524	.1261	.1050	333.144	6.724	6.618	6.003
17.5	.9492	7.905	9.492	.1265	.1054	332.010	6.747	6.640	6.024
18.	.9459	7.878	9.459	.1269	.1057	330.876	6.770	6.663	6.045
18.5	.9428	7.852	9.428	.1274	.1061	329.784	6.792	6.685	6.065
19.	.9396	7.825	9.396	.1278	.1064	328.650	6.816	6.708	6.086
19.5	.9365	7.799	9.365	.1282	.1068	327.558	6.838	6.730	6.106
20.	.9333	7.773	9.333	.1287	.1071	326.466	6.861	6.753	6.126
20.5	.9302	7.747	9.302	.1291	.1075	325.374	6.884	6.776	6.147
21.	.9272	7.722	9.272	.1295	.1079	324.324	6.907	6.798	6.167
21.5	.9241	7.696	9.241	.1299	.1082	323.232	6.930	6.821	6.188
22.	.9211	7.671	9.211	.1304	.1086	322.182	6.953	6.843	6.208
22.5	.9180	7.645	9.180	.1308	.1089	321.090	6.976	6.866	6.229
23.	.9150	7.620	9.150	.1312	.1093	320.040	6.999	6.889	6.249
23.5	.9121	7.596	9.121	.1316	.1096	319.032	7.021	6.910	6.269
24.	.9091	7.571	9.091	.1321	.1100	317.982	7.044	6.933	6.290
24.5	.9061	7.546	9.061	.1325	.1104	316.932	7.068	6.956	6.311
25.	.9032	7.522	9.032	.1329	.1107	315.924	7.090	6.978	6.331
25.5	.9003	7.498	9.003	.1334	.1111	314.916	7.113	7.001	6.351
26.	.8974	7.474	8.974	.1338	.1114	313.908	7.136	7.023	6.371
26.5	.8946	7.450	8.946	.1342	.1118	312.900	7.159	7.046	6.392
27.	.8917	7.426	8.917	.1347	.1121	311.892	7.182	7.069	6.412
27.5	.8889	7.403	8.889	.1351	.1125	310.926	7.204	7.091	6.432
28.	.8861	7.380	8.861	.1355	.1129	309.960	7.227	7.113	6.452
28.5	.8833	7.356	8.833	.1359	.1132	308.952	7.250	7.136	6.473
29.	.8805	7.333	8.805	.1364	.1136	307.986	7.273	7.158	6.494
29.5	.8777	7.310	8.777	.1368	.1139	307.020	7.296	7.181	6.514
30.	.8750	7.287	8.750	.1372	.1143	306.054	7.319	7.203	6.535
30.5	.8723	7.265	8.723	.1376	.1146	305.130	7.341	7.225	6.555
31.	.8696	7.242	8.696	.1381	.1150	304.164	7.364	7.248	6.575
31.5	.8669	7.220	8.669	.1385	.1154	303.240	7.387	7.270	6.595
32.	.8642	7.197	8.642	.1389	.1157	302.274	7.410	7.293	6.617
32.5	.8615	7.175	8.615	.1394	.1161	301.350	7.433	7.316	6.637
33.	.8589	7.153	8.589	.1398	.1164	300.426	7.456	7.338	6.657
33.5	.8563	7.131	8.563	.1402	.1168	299.502	7.479	7.361	6.678

AT 60 DEGREES F.

Lbs. per Cu. Ft. (Constant 7.48052)	Cu. Ft. per Long Ton (2240 Lbs.)	Cu. Ft. per Metric Ton (2204.6223 Lbs.)	Cu. Ft. per Short Ton (2000 Lbs.)	Gallons per Long Ton (2240 Lbs.)	Imp. Gallons per Long Ton (2240 Lbs.)	Gallons per Metric Ton (2204.6223 Lbs.)	Imp. Gallons per Metric Ton (2204.6223 Lbs.)	Gallons per Short Ton (2000 Lbs.)	Imp. Gallons per Short Ton (2000 Lbs.)
62.298	35.956	35.388	32.104	268.972	224.000	264.724	220.462	240.154	200.000
62.073	36.087	35.517	32.220	269.945	224.809	265.681	221.259	241.022	200.723
61.856	36.213	35.641	32.333	270.891	225.602	266.613	222.039	241.867	201.430
61.639	36.341	35.767	32.447	271.845	226.400	267.551	222.824	242.718	202.143
61.423	36.468	35.892	32.561	272.805	227.204	268.496	223.615	243.576	202.860
61.206	36.598	36.020	32.677	273.772	227.990	269.448	224.389	244.439	203.562
60.989	36.728	36.148	32.793	274.745	228.805	270.406	225.191	245.308	204.290
60.779	36.855	36.273	32.906	275.692	229.602	271.338	225.976	246.154	205.002
60.570	36.982	36.398	33.020	276.646	230.405	272.276	226.766	247.005	205.719
60.360	37.111	36.525	33.135	277.606	231.190	273.221	227.539	247.862	206.420
60.151	37.240	36.651	33.250	278.572	232.004	274.173	228.340	248.725	207.147
59.941	37.370	36.780	33.366	279.546	232.800	275.131	229.123	249.594	207.857
59.739	37.496	36.904	33.479	280.491	233.601	276.061	229.912	250.438	208.572
59.530	37.628	37.034	33.597	281.478	234.408	277.032	230.706	251.319	209.293
59.335	37.752	37.156	33.707	282.400	235.195	277.940	231.481	252.143	209.996
59.134	37.880	37.282	33.821	283.365	235.988	278.890	232.261	253.004	210.704
58.932	38.010	37.410	33.937	284.336	236.812	279.845	233.071	253.872	211.439
58.737	38.136	37.534	34.050	285.278	237.590	280.772	233.838	254.712	212.134
58.535	38.268	37.663	34.168	286.262	238.399	281.741	234.634	255.591	212.857
58.341	38.395	37.789	34.281	287.216	239.188	282.680	235.411	256.443	213.561
58.146	38.524	37.915	34.396	288.177	240.009	283.626	236.218	257.301	214.293
57.952	38.653	38.042	34.511	289.144	240.808	284.578	237.005	258.164	215.008
57.765	38.778	38.165	34.623	290.080	241.588	285.499	237.772	259.000	215.703
57.570	38.909	38.295	34.740	291.060	242.398	286.463	238.570	259.875	216.427
57.383	39.036	38.419	34.854	292.009	243.187	287.397	239.347	260.722	217.132
57.189	39.168	38.550	34.972	293.002	244.009	288.374	240.155	261.609	217.865
57.002	39.297	38.676	35.086	293.963	244.809	289.321	240.942	262.467	218.579
56.822	39.421	38.799	35.198	294.892	245.587	290.235	241.708	263.296	219.274
56.635	39.552	38.927	35.314	295.866	246.398	291.193	242.506	264.166	219.998
56.448	39.683	39.056	35.431	296.846	247.213	292.158	243.309	265.041	220.726
56.268	39.809	39.181	35.544	297.793	248.007	293.090	244.090	265.887	221.435
56.089	39.936	39.306	35.658	298.746	248.806	294.028	244.876	266.738	222.148
55.909	40.065	39.432	35.772	299.706	249.610	294.972	245.668	267.594	222.866
55.730	40.194	39.559	35.887	300.671	250.391	295.922	246.437	268.456	223.564
55.550	40.324	39.687	36.004	301.643	251.206	296.879	247.238	269.324	224.291
55.378	40.449	39.810	36.115	302.580	251.997	297.801	248.017	270.161	224.997
55.206	40.575	39.934	36.228	303.523	252.793	298.729	248.801	271.003	225.708
55.027	40.707	40.064	36.346	304.513	253.594	299.704	249.589	271.887	226.424
54.855	40.835	40.190	36.460	305.468	254.401	300.644	250.383	272.740	227.144
54.683	40.963	40.316	36.574	306.430	255.212	301.590	251.182	273.598	227.868
54.511	41.093	40.444	36.690	307.397	256.000	302.542	251.957	274.461	228.571
54.346	41.217	40.566	36.801	308.328	256.792	303.458	252.737	275.292	229.279
54.174	41.348	40.695	36.918	309.307	257.590	304.422	253.521	276.167	229.991
54.009	41.475	40.820	37.031	310.249	258.392	305.349	254.311	277.008	230.707
53.837	41.607	40.950	37.149	311.241	259.199	306.325	255.106	277.894	231.428
53.673	41.734	41.075	37.263	312.195	260.012	307.264	255.905	278.746	232.153
53.508	41.863	41.202	37.378	313.155	260.799	308.209	256.680	279.603	232.856
53.344	41.992	41.328	37.493	314.121	261.591	309.160	257.459	280.466	233.563

OIL MEASUREMENT TABLE

Beaumé Gravity	Specific Gravity	Lbs. per Gallon	Lbs. per Imp. Gallon	Gallons per Lb.	Imp. Gallons per Lb.	Lbs. per Barrel	Barrels per Long Ton (2240 Lbs.)	Barrels per Metric Ton (2204.6223 Lbs.)	Barrels per Short Ton (2000 Lbs.)
34.	.8537	7.110	8.537	.1406	.1171	298.620	7.501	7.383	6.697
34.5	.8511	7.088	8.511	.1411	.1175	297.696	7.524	7.406	6.718
35.	.8485	7.067	8.485	.1415	.1179	296.814	7.547	7.428	6.738
35.5	.8459	7.045	8.459	.1419	.1182	295.890	7.570	7.451	6.759
36.	.8434	7.024	8.434	.1424	.1186	295.008	7.593	7.473	6.779
36.5	.8408	7.002	8.408	.1428	.1189	294.084	7.617	7.497	6.801
37.	.8383	6.982	8.383	.1432	.1193	293.244	7.639	7.518	6.820
37.5	.8358	6.961	8.358	.1437	.1196	292.362	7.662	7.541	6.841
38.	.8333	6.940	8.333	.1441	.1200	291.480	7.685	7.564	6.862
38.5	.8309	6.920	8.309	.1445	.1204	290.640	7.707	7.585	6.881
39.	.8284	6.899	8.284	.1449	.1207	289.758	7.731	7.608	6.902
39.5	.8260	6.879	8.260	.1454	.1211	288.918	7.753	7.631	6.922
40.	.8235	6.858	8.235	.1458	.1214	288.036	7.777	7.654	6.944
40.5	.8211	6.838	8.211	.1462	.1218	287.196	7.800	7.676	6.964
41.	.8187	6.818	8.187	.1467	.1221	286.356	7.822	7.699	6.984
41.5	.8163	6.798	8.163	.1471	.1225	285.516	7.845	7.722	7.005
42.	.8140	6.779	8.140	.1475	.1229	284.718	7.867	7.743	7.024
42.5	.8116	6.759	8.116	.1480	.1232	283.878	7.891	7.766	7.045
43.	.8092	6.739	8.092	.1484	.1236	283.038	7.914	7.789	7.066
43.5	.8069	6.720	8.069	.1488	.1239	282.240	7.937	7.811	7.086
44.	.8046	6.701	8.046	.1492	.1243	281.442	7.959	7.833	7.106
44.5	.8023	6.682	8.023	.1497	.1246	280.644	7.982	7.856	7.126
45.	.8000	6.663	8.000	.1501	.1250	279.846	8.004	7.878	7.147
45.5	.7977	6.643	7.977	.1505	.1254	279.006	8.029	7.902	7.168
46.	.7955	6.625	7.955	.1509	.1257	278.250	8.050	7.923	7.188
46.5	.7932	6.606	7.932	.1514	.1261	277.452	8.073	7.946	7.208
47.	.7910	6.588	7.910	.1518	.1264	276.696	8.096	7.968	7.228
47.5	.7887	6.568	7.887	.1523	.1268	275.856	8.120	7.992	7.250
48.	.7865	6.550	7.865	.1527	.1271	275.100	8.142	8.014	7.270
48.5	.7843	6.532	7.843	.1531	.1275	274.344	8 165	8.036	7.290
49.	.7821	6.514	7.821	.1535	.1279	273.588	8.187	8.058	7.310
49.5	.7799	6.495	7.799	.1540	.1282	272.790	8.211	8.082	[illegible]
50.	.7778	6.478	7.778	.1544	.1286	272.076	8.233	8.103	7.351
50.5	.7756	6.459	7.756	.1548	.1289	271.278	8.257	8.127	7.373
51.	.7735	6.442	7.735	.1552	.1293	270.564	8.279	8.148	[illegible]
51.5	.7713	6.424	7.713	.1557	.1297	269.808	8.302	8.171	7.413
52.	.7692	6.406	7.692	.1561	.1300	269.052	8.326	8.194	7.434
52.5	.7671	6.389	7.671	.1565	.1304	268.338	8.348	8.216	7.455
53.	.7650	6.371	7.650	.1570	.1307	267.582	8.371	8.239	7.474
53.5	.7629	6.354	7.629	.1574	.1311	266.868	8.394	8.261	[illegible]
54.	.7609	6.337	7.609	.1578	.1314	266.154	8.416	8.283	7.514
54.5	.7588	6.319	7.588	.1583	.1318	265.398	8.440	8.307	7.536
55.	.7568	6.303	7.568	.1587	.1321	264.726	8.462	8.328	[illegible]
55.5	.7547	6.285	7.547	.1591	.1325	263.970	8.486	8.352	7.577
56.	.7527	6.269	7.527	.1595	.1329	263.298	8.507	8.373	[illegible]
56.5	.7507	6.252	7.507	.1599	.1332	262.584	8.531	8.396	[illegible]
57.	.7487	6.235	7.487	.1604	.1336	261.870	8.554	8.419	[illegible]
57.5	.7467	6.219	7.467	.1608	.1339	261.198	8.576	8.440	[illegible]

AT 60 DEGREES F.—*Continued.*

Lbs. per Cu. Ft. (Constant 7.48052)	Cu. Ft. per Long Ton (2240 Lbs.)	Cu. Ft. per Metric Ton (2204.6223 Lbs.)	Cu. Ft. per Short Ton (2000 Lbs.)	Gallons per Long Ton (2240 Lbs.)	Imp. Gallons per Long Ton (2240 Lbs.)	Gallons per Metric Ton (2204.6223 Lbs.)	Imp. Gallons per Metric Ton (2204.6223 Lbs.)	Gallons per Short Ton (2000 Lbs.)	Imp. Gallons per Short Ton (2000 Lbs.)
53.186	42.116	41.451	37.604	315.049	262.387	310.073	258.243	281.294	234.274
53.022	42.247	41.579	37.720	316.027	263.189	311.036	259.032	282.167	234.990
52.865	42.372	41.703	37.832	316.966	263.995	311.960	259.826	283.006	235.710
52.700	42.505	41.833	37.951	317.956	264.807	312.934	260.624	283.889	236.435
52.543	42.632	41.958	38.064	318.907	265.592	313.870	261.397	284.738	237.135
52.379	42.765	42.090	38.183	319.909	266.413	314.856	262.205	285.633	237.869
52.229	42.888	42.211	38.293	320.825	267.207	315.758	262.987	286.451	238.578
52.072	43.017	42.338	38.408	321.793	268.007	316.711	263.774	287.315	239.292
51.915	43.147	42.466	38.525	322.767	268.811	317.669	264.565	288.184	240.010
51.765	43.272	42.589	38.636	323.699	269.587	318.587	265.329	289.017	240.703
51.608	43.404	42.719	38.754	324.685	270.401	319.557	266.130	289.897	241.429
51.458	43.531	42.843	38.867	325.629	271.186	320.486	266.903	290.740	242.131
51.301	43.664	42.974	38.986	326.626	272.010	321.467	267.714	291.630	242.866
51.152	43.791	43.099	39.099	327.581	272.805	322.407	268.496	292.483	243.576
51.002	43.920	43.226	39.214	328.542	273.604	323.353	269.283	293.341	244.290
50.853	44.049	43.353	39.329	329.509	274.409	324.305	270.075	294.204	245.008
50.710	44.173	43.475	39.440	330.432	275.184	325.213	270.838	295.029	245.700
50.561	44.303	43.603	39.556	331.410	275.998	326.176	271.639	295.902	246.427
50.411	44.435	43.733	39.674	332.394	276.817	327.144	272.445	296.780	247.158
50.269	44.560	43.856	39.786	333.333	277.606	328.069	273.221	297.619	247.862
50.127	44.686	43.981	39.899	334.278	278.399	328.999	274.002	298.463	248.571
49.985	44.813	44.106	40.012	335.229	279.197	329.934	274.788	299.312	249.283
49.843	44.941	44.231	40.126	336.185	280.000	330.875	275.578	300.165	250.000
49.693	45.077	44.365	40.247	337.197	280.807	331.871	276.372	301.069	250.721
49.558	45.200	44.486	40.357	338.113	281.584	332.773	277.137	301.887	251.414
49.416	45.329	44.614	40.473	339.086	282.400	333.730	277.940	302.755	252.143
49.282	45.453	44.735	40.583	340.012	283.186	334.642	278.713	303.582	252 845
49.132	45.591	44.871	40.707	341.048	284.012	335.661	279.526	304.507	253.582
48.997	45.717	44.995	40.819	341.985	284.806	336.584	280.308	305.344	254.291
48.863	45.842	45.118	40.931	342.927	285.605	337.511	281.094	306.185	255.004
48.728	45.969	45.243	41.044	343.875	286.408	338.444	281.885	307.031	255.722
48.586	46.104	45.376	41.164	344.881	287.216	339.434	282.680	307.929	256.443
48.459	46.225	45.495	41.272	345.786	287.992	340.325	283.443	308.737	257.136
48.317	46.360	45.628	41.393	346.803	288.809	341.326	284.247	309.645	257.865
48.190	46.483	45.749	41.502	347.718	289.593	342.226	285.019	310.463	258.565
48.055	46.613	45.877	41.619	348.692	290.419	343.185	285.832	311.333	259.302
47.920	46.745	46.006	41.736	349.672	291.212	344.150	286.612	312.207	260.010
47.793	46.869	46.129	41.847	350.603	292.009	345.065	287.397	313.038	260.722
47.658	47.002	46.259	41.966	351.593	292.810	346.040	288.186	313.922	261.438
47.531	47.127	46.383	42.078	352.534	293.616	346.966	288.979	314.762	262.158
47.404	47.253	46.507	42.191	353.480	294.388	347.897	289.739	315.607	262.847
47.269	47.388	46.640	42.311	354.486	295.203	348.888	290.541	316.506	263.574
47.150	47.508	46.758	42.418	355.386	295.983	349.773	291.308	317.309	264.271
47.015	47.644	46.892	42.540	356.404	296.807	350.775	292.119	318.218	265.006
46.895	47.766	47.012	42.648	357.314	297.595	351.670	292.895	319.030	265.710
46.768	47.896	47.140	42.764	358.285	298.388	352.627	293.676	319.898	266.418
46.641	48.026	47.268	42.881	359.262	299.185	353.588	294.460	320.770	267.130
46.521	48.150	47.390	42.991	360.187	299.987	354.498	295.249	321.595	267.845

OIL MEASUREMENT TABLE

Baumé Gravity	Specific Gravity	Lbs. per Gallon	Lbs. per Imp. Gallon	Gallons per Lb.	Imp. Gallons per Lb.	Lbs. per Barrel	Barrels per Long Ton (2240 Lbs.)	Barrels per Metric Ton (2204.6223 Lbs.)	Barrels per Short Ton (2000 Lbs.)
58.	.7447	6.202	7.447	.1612	.1343	260.484	8.599	8.464	7.678
58.5	.7427	6.185	7.427	.1617	.1346	259.770	8.623	8.487	7.699
59.	.7407	6.169	7.407	.1621	.1350	259.098	8.645	8.509	7.719
59.5	.7388	6.153	7.388	.1625	.1354	258.426	8.668	8.531	7.739
60.	.7368	6.136	7.368	.1630	.1357	257.712	8.692	8.555	7.761
60.5	.7349	6.120	7.349	.1634	.1361	257.040	8.715	8.577	7.781
61.	.7330	6.105	7.330	.1638	.1364	256.410	8.736	8.598	7.800
61.5	.7311	6.089	7.311	.1642	.1368	255.738	8.759	8.621	7.821
62.	.7292	6.073	7.292	.1647	.1371	255.066	8.782	8.643	7.841
62.5	.7273	6.057	7.273	.1651	.1375	254.394	8.805	8.666	7.862
63.	.7254	6.041	7.254	.1655	.1379	253.722	8.829	8.689	7.883
63.5	.7235	6.025	7.235	.1660	.1382	253.050	8.852	8.712	7.904
64.	.7216	6.010	7.216	.1664	.1386	252.420	8.874	8.734	7.923
64.5	.7198	5.995	7.198	.1668	.1389	251.790	8.896	8.756	7.943
65.	.7179	5.979	7.179	.1673	.1393	251.118	8.920	8.779	7.964
65.5	.7161	5.964	7.161	.1677	.1396	250.488	8.943	8.801	7.984
66.	.7143	5.949	7.143	.1681	.1400	249.858	8.965	8.824	8.005
66.5	.7125	5.934	7.125	.1685	.1404	249.228	8.988	8.846	8.025
67.	.7107	5.919	7.107	.1689	.1407	248.598	9.011	8.868	8.045
67.5	.7089	5.904	7.089	.1694	.1411	247.968	9.033	8.891	8.066
68.	.7071	5.889	7.071	.1698	.1414	247.338	9.056	8.913	8.086
68.5	.7053	5.874	7.053	.1702	.1418	246.708	9.080	8.936	8.107
69.	.7035	5.859	7.035	.1707	.1421	246.078	9.103	8.959	8.128
69.5	.7018	5.845	7.018	.1711	.1425	245.490	9.125	8.980	8.147
70.	.7000	5.830	7.000	.1715	.1429	244.860	9.148	9.004	8.168
70.5	.6983	5.816	6.983	.1719	.1432	244.272	9.170	9.025	8.188
71.	.6965	5.801	6.965	.1724	.1436	243.642	9.194	9.049	8.209
71.5	.6948	5.786	6.948	.1728	.1439	243.012	9.218	9.072	8.230
72.	.6931	5.772	6.931	.1733	.1443	242.424	9.240	9.094	8.250
72.5	.6914	5.758	6.914	.1737	.1446	241.836	9.262	9.116	8.270
73.	.6897	5.744	6.897	.1741	.1450	241.248	9.285	9.138	8.290
73.5	.6880	5.730	6.880	.1745	.1453	240.660	9.308	9.161	8.310
74.	.6863	5.716	6.863	.1749	.1457	240.072	9.331	9.183	8.331
74.5	.6846	5.702	6.846	.1754	.1461	239.484	9.353	9.206	8.351
75.	.6829	5.687	6.829	.1758	.1464	238.854	9.378	9.230	8.373
75.5	.6813	5.674	6.813	.1762	.1468	238.308	9.400	9.251	8.393
76.	.6796	5.660	6.796	.1767	.1471	237.720	9.423	9.274	8.413
76.5	.6780	5.647	6.780	.1771	.1475	237.174	9.445	9.295	8.433
77.	.6763	5.632	6.763	.1776	.1479	236.544	9.470	9.320	8.455
77.5	.6747	5.619	6.747	.1780	.1482	235.998	9.492	9.342	8.475
78.	.6731	5.606	6.731	.1784	.1486	235.452	9.514	9.363	8.494
78.5	.6715	5.592	6.715	.1788	.1489	234.864	9.537	9.387	8.516
79.	.6699	5.579	6.699	.1792	.1493	234.318	9.560	9.409	8.535
79.5	.6683	5.566	6.683	.1797	.1496	233.772	9.582	9.431	8.555
80.	.6667	5.552	6.667	.1801	.1500	233.184	9.606	9.454	8.577
80.5	.6651	5.539	6.651	.1805	.1504	232.638	9.629	9.477	8.597
81.	.6635	5.526	6.635	.1810	.1507	232.092	9.651	9.499	8.617
81.5	.6619	5.512	6.619	.1814	.1511	231.504	9.676	9.523	8.639

AT 60 DEGREES F.—*Continued.*

Lbs. per Cu. Ft. (Constant 7.48052)	Cu. Ft. per Long Ton (2240 Lbs.)	Cu. Ft. per Metric Ton (2204.6223 Lbs.)	Cu. Ft. per Short Ton (2000 Lbs.)	Gallons per Long Ton (2240 Lbs.)	Imp. Gallons per Long Ton (2240 Lbs.)	Gallons per Metric Ton (2204.6223 Lbs.)	Imp. Gallons per Metric Ton (2204.6223 Lbs.)	Gallons per Short Ton (2000 Lbs.)	Imp. Gallons per Short Ton (2000 Lbs.)
46.394	48.282	47.520	43.109	361.174	300.792	355.470	296.042	322.477	268.565
46.267	48.415	47.650	43.227	362.167	301.602	356.447	296.839	323.363	269.288
46.147	48.541	47.774	43.340	363.106	302.417	357.371	297.640	324.202	270.015
46.028	48.666	47.897	43.452	364.050	303.194	358.300	298.406	325.045	270.709
45.900	48.802	48.031	43.573	365.059	304.017	359.293	299.216	325.945	271.444
45.781	48.929	48.156	43.686	366.013	304.803	360.232	299.989	326.797	272.146
45.669	49.049	48.274	43.793	366.912	305.593	361.117	300.767	327.600	272.851
45.549	49.178	48.401	43.909	367.876	306.388	362.066	301.549	328.461	273.560
45.429	49.308	48.529	44.025	368.846	307.186	363.020	302.334	329.327	274.273
45.310	49.437	48.656	44.140	369.820	307.988	363.979	303.124	330.196	274.990
45.190	49.568	48.786	44.258	370.800	308.795	364.943	303.918	331.071	275.710
45.070	49.700	48.916	44.375	371.784	309.606	365.912	304.716	331.950	276.434
44.958	49.824	49.037	44.486	372.712	310.421	366.826	305.519	332.779	277.162
44.846	49.949	49.160	44.597	373.645	311.198	367.744	306.283	333.611	277.855
44.726	50.083	49.292	44.717	374.645	312.021	368.728	307.093	334.504	278.590
44.614	50.208	49.415	44.829	375.587	312.805	369.655	307.865	335.345	279.291
44.502	50.335	49.540	44.942	376.534	313.594	370.587	308.641	336.191	279.994
44.389	50.463	49.666	45.056	377.486	314.386	371.524	309.421	337.041	280.702
44.277	50.591	49.792	45.170	378.442	315.182	372.465	310.204	337.895	281.413
44.165	50.719	49.918	45.285	379.404	315.983	373.412	310.992	338.753	282.127
44.053	50.848	50.045	45.400	380.370	316.787	374.363	311.784	339.616	282.845
43.941	50.977	50.172	45.516	381.342	317.595	375.319	312.579	340.483	283.567
43.828	51.109	50.302	45.633	382.318	318.408	376.280	313.379	341.355	284.293
43.724	51.230	50.421	45.741	383.234	319.179	377.181	314.138	342.173	284.981
43.611	51.363	50.552	45.860	384.220	320.000	378.151	314.946	343.053	285.714
43.507	51.486	50.673	45.970	385.144	320.779	379.062	315.713	343.879	286.410
43.394	51.620	50.805	46.089	386.140	321.608	380.042	316.529	344.768	287.150
43.282	51.754	50.936	46.209	387.141	322.395	381.027	317.303	345.662	287.853
43.178	51.878	51.059	46.320	388.080	323.186	381.951	318.081	346.500	288.559
43.073	52.005	51.183	46.433	389.024	323.980	382.880	318.864	347.343	289.268
42.968	52.132	51.308	46.546	389.972	324.779	383.813	319.649	348.189	289.981
42.863	52.260	51.434	46.660	390.925	325.581	384.751	320.439	349.040	290.698
42.759	52.387	51.559	46.774	391.882	326.388	385.693	321.233	349.895	291.418
42.654	52.516	51.686	46.889	392.845	327.198	386.640	322.031	350.754	292.141
42.542	52.654	51.822	47.012	393.881	328.013	387.660	322.832	351.679	292.869
42.444	52.775	51.942	47.121	394.783	328.783	388.548	323.591	352.485	293.556
42.340	52.905	52.069	47.237	395.760	329.606	389.509	324.400	353.357	294.291
42.242	53.028	52.190	47.346	396.671	330.383	390.406	325.166	354.170	294.985
42.130	53.169	52.329	47.472	397.727	331.214	391.446	325.983	355.114	295.727
42.033	53.291	52.450	47.582	398.647	331.999	392.351	326.756	355.935	296.428
41.936	53.415	52.571	47.692	399.572	332.789	393.261	327.533	356.761	297.133
41.831	53.549	52.703	47.811	400.572	333.582	394.246	328.313	357.654	297.841
41.734	53.673	52.826	47.923	401.506	334.378	395.164	329.097	358.487	298.582
41.637	53.798	52.949	48.034	402.443	335.179	396.087	329.885	359.324	299.267
41.532	53.934	53.082	48.156	403.458	335.983	397.086	330.677	360.231	299.985
41.435	54.061	53.207	48.268	404.405	336.791	398.018	331.472	361.076	300.707
41.337	54.189	53.333	48.383	405.356	337.604	398.954	332.272	361.925	301.432
41.233	54.325	53.467	48.505	406.386	338.420	399.968	333.075	362.845	302.160

OIL MEASUREMENT TABLE

Baumé Gravity	Specific Gravity	Lbs. per Gallon	Lbs. per Imp. Gallon	Gallons per Lb.	Imp. Gallons per Lb.	Lbs. per Barrel	Barrels per Long Ton (2240 Lbs.)	Barrels per Metric Ton (2204.6223 Lbs.)	Barrels per Short Ton (2000 Lbs.)
82.	.6604	5.500	6.604	.1818	.1514	231.000	9.697	9.544	8.658
82.5	.6588	5.487	6.588	.1822	.1518	230.454	9.720	9.566	8.679
83.	.6573	5.474	6.573	.1827	.1521	229.908	9.743	9.589	8.699
83.5	.6557	5.461	6.557	.1831	.1525	229.362	9.766	9.612	8.720
84.	.6542	5.448	6.542	.1836	.1529	228.816	9.790	9.635	8.741
84.5	.6527	5.436	6.527	.1840	.1532	228.312	9.811	9.656	8.760
85.	.6512	5.423	6.512	.1844	.1536	227.766	9.835	9.679	8.781
85.5	.6497	5.411	6.497	.1848	.1539	227.262	9.856	9.701	8.800
86.	.6481	5.398	6.481	.1853	.1543	226.716	9.880	9.724	8.822
86.5	.6467	5.386	6.467	.1857	.1546	226.212	9.902	9.746	8.841
87.	.6452	5.373	6.452	.1861	.1550	225.666	9.926	9.769	8.863
87.5	.6437	5.361	6.437	.1865	.1554	225.162	9.948	9.791	8.882
88.	.6422	5.348	6.422	.1870	.1557	224.616	9.973	9.815	8.904
88.5	.6407	5.336	6.407	.1874	.1561	224.112	9.995	9.837	8.924
89.	.6393	5.324	6.393	.1878	.1564	223.608	10.018	9.859	8.944
89.5	.6378	5.312	6.378	.1883	.1568	223.104	10.040	9.882	8.964
90.	.6364	5.300	6.364	.1887	.1571	222.600	10.063	9.904	8.985
90.5	.6349	5.288	6.349	.1891	.1575	222.096	10.086	9.926	9.005
91.	.6335	5.276	6.335	.1895	.1579	221.592	10.109	9.949	9.026
91.5	.6321	5.264	6.321	.1900	.1582	221.088	10.132	9.972	9.046
92.	.6306	5.252	6.306	.1904	.1586	220.584	10.155	9.994	9.067
92.5	.6292	5.240	6.292	.1908	.1589	220.080	10.178	10.017	9.088
93.	.6278	5.228	6.278	.1913	.1593	219.576	10.201	10.040	9.108
93.5	.6264	5.217	6.264	.1917	.1596	219.114	10.223	10.062	9.128
94.	.6250	5.205	6.250	.1921	.1600	218.610	10.247	10.085	9.149
94.5	.6236	5.193	6.236	.1926	.1604	218.106	10.270	10.108	9.170
95.	.6222	5.182	6.222	.1930	.1607	217.644	10.292	10.129	9.189
95.5	.6208	5.170	6.208	.1934	.1611	217.140	10.316	10.153	9.211
96.	.6195	5.159	6.195	.1938	.1614	216.678	10.338	10.175	9.230
96.5	.6181	5.148	6.181	.1943	.1618	216.216	10.360	10.196	9.250
97.	.6167	5.136	6.167	.1947	.1622	215.712	10.384	10.220	9.272
97.5	.6154	5.125	6.154	.1951	.1625	215.250	10.407	10.242	9.292
98.	.6140	5.114	6.140	.1955	.1629	214.788	10.429	10.264	9.312
98.5	.6127	5.103	6.127	.1960	.1632	214.326	10.451	10.286	9.332
99.	.6114	5.092	6.114	.1964	.1636	213.864	10.474	10.309	9.352
99.5	.6100	5.080	6.100	.1969	.1639	213.360	10.499	10.333	9.374
100.	.6087	5.069	6.087	.1973	.1643	212.898	10.521	10.355	9.394

AT 60 DEGREES F.—*Concluded.*

Lbs. per Cu. Ft. (Constant 7.48052)	Cu. Ft. per Long Ton (2240 Lbs.)	Cu. Ft. per Metric Ton (2204.6223Lbs.)	Cu. Ft. per Short Ton (2000 Lbs.)	Gallons per Long Ton (2240 Lbs.)	Imp. Gallons per Long Ton (2240 Lbs.)	Gallons per Metric Ton (2204.6223Lbs.)	Imp. Gallons per Metric Ton (2204.6223Lbs.)	Gallons per Short Ton (2000 Lbs.)	Imp. Gallons per Short Ton (2000 Lbs.)
41.143	54.444	53.584	48.611	407.273	339.188	400.840	333.831	363.636	302.847
41.046	54.573	53.711	48.726	408.238	340.012	401.790	334.642	364.498	303.582
40.948	54.704	53.840	48.842	409.207	340.788	402.744	335.406	365.364	304.275
40.851	54.833	53.967	48.958	410.181	341.620	403.703	336.224	366.233	305.018
40.754	54.964	54.096	49.075	411.160	342.403	404.666	336.995	367.107	305.717
40.664	55.086	54.216	49.184	412.068	343.190	405.560	337.770	367.918	306.419
40.567	55.217	54.345	49.301	413.056	343.980	406.532	338.548	368.800	307.125
40.477	55.340	54.466	49.411	413.972	344.775	407.433	339.329	369.617	307.834
40.380	55.473	54.597	49.529	414.969	345.626	408.415	340.167	370.508	308.594
40.290	55.597	54.719	49.640	415.893	346.374	409.325	340.903	371.333	309.262
40.193	55.731	54.851	49.760	416.899	347.179	410.315	341.696	372.232	309.981
40.103	55.856	54.974	49.872	417.832	347.988	411.233	342.492	373.065	310.704
40.006	55.992	55.107	49.993	418.848	348.801	412.233	343.292	373.972	311.429
39.916	56.118	55.232	50.105	419.790	349.618	413.160	344.096	374.813	312.159
39.826	56.245	55.356	50.218	420.736	350.383	414.091	344.849	375.657	312.842
39.737	56.371	55.480	50.331	421.687	351.207	415.027	345.660	376.506	313.578
39.647	56.499	55.606	50.445	422.642	351.980	415.966	346.421	377.358	314.268
39.557	56.627	55.733	50.560	423.601	352.811	416.910	347.239	378.215	315.010
39.467	56.756	55.860	50.675	424.564	353.591	417.859	348.007	379.075	315.706
39.377	56.886	55.988	50.791	425.532	354.374	418.811	348.777	379.939	316.406
39.288	57.015	56.114	50.906	426.504	355.217	419.768	349.607	380.807	317.158
39.198	57.146	56.243	51.023	427.481	356.008	420.729	350.385	381.679	317.864
39.108	57.277	56.373	51.140	428.462	356.802	421.695	351.166	382.555	318.573
39.026	57.398	56.491	51.248	429.366	357.599	422.584	351.951	383.362	319.285
38.936	57.530	56.622	51.366	430.355	358.400	423.559	352.740	384.246	320.000
38.846	57.664	56.753	51.485	431.350	359.205	424.537	353.531	385.134	320.718
38.764	57.786	56.873	51.594	432.266	360.013	425.438	354.327	385.951	321.440
38.674	57.920	57.005	51.714	433.269	360.825	426.426	355.126	386.847	322.165
38.592	58.043	57.126	51.824	434.193	361.582	427.335	355.871	387.672	322.841
38.510	58.167	57.248	51.935	435.120	362.401	428.248	356.677	388.500	323.572
38.420	58.303	57.382	52.056	436.137	363.224	429.249	357.487	389.408	324.307
38.338	58.428	57.505	52.168	437.073	363.991	430.170	358.242	390.244	324.992
38.255	58.554	57.630	52.281	438.013	364.821	431.095	359.059	391.083	325.733
38.173	58.680	57.753	52.393	438.957	365.595	432.025	359.821	391.926	326.424
38.091	58.807	57.878	52.506	439.906	366.372	432.958	360.586	392.773	327.118
38.001	58.946	58.015	52.630	440.945	367.213	433.981	361.413	393.701	327.869
37.919	59.073	58.140	52.744	441.902	367.997	434.923	362.185	394.555	328.569

WEIGHT OF ASPHALT OF VARIOUS PENETRATIONS

Based on curve drawn from specific gravities at 60 degrees F., determined by THE BUREAU OF STANDARDS.

Weights computed from the weight of water at 4° C. weighed in air, given by THE BUREAU OF STANDARDS as 8.3358 pounds per gallon.

40°	8.7024	65°	8.6696	90°	8.6401	115°	8.6142
41°	8.7010	66°	8.6684	91°	8.6390	116°	8.6132
42°	8.6996	67°	8.6671	92°	8.6379	117°	8.6122
43°	8.6983	68°	8.6659	93°	8.6369	118°	8.6111
44°	8.6969	69°	8.6646	94°	8.6359	119°	8.6102
45°	8.6955	70°	8.6634	95°	8.6347	120°	8.6091
46°	8.6942	71°	8.6621	96°	8.6336	121°	8.6081
47°	8.6928	72°	8.6609	97°	8.6326	122°	8.6071
48°	8.6916	73°	8.6598	98°	8.6316	123°	8.6061
49°	8.6901	74°	8.6586	99°	8.6306	124°	8.6050
50°	8.6888	75°	8.6573	100°	8.6296	125°	8.6040
51°	8.6876	76°	8.6562	101°	8.6286	126°	8.6030
52°	8.6862	77°	8.6550	102°	8.6276	127°	8.6020
53°	8.6849	78°	8.6538	103°	8.6265	128°	8.6010
54°	8.6835	79°	8.6526	104°	8.6255	129°	8.6000
55°	8.6822	80°	8.6514	105°	8.6244	130°	8.5990
56°	8.6809	81°	8.6503	106°	8.6234	131°	8.5980
57°	8.6797	82°	8.6492	107°	8.6224	132°	8.5970
58°	8.6784	83°	8.6480	108°	8.6214	133°	8.5959
59°	8.6772	84°	8.6470	109°	8.6204	134°	8.5949
60°	8.6759	85°	8.6457	110°	8.6194	135°	8.5938
61°	8.6747	86°	8.6446	111°	8.6183	136°	8.5928
62°	8.6734	87°	8.6434	112°	8.6173	137°	8.5918
63°	8.6721	88°	8.6423	113°	8.6163	138°	8.5907
64°	8.6709	89°	8.6412	114°	8.6152	139°	8.5897

WEIGHT OF ASPHALT OF VARIOUS PENETRATIONS

Based on curve from specific gravities at 77° F. determined by THE BUREAU OF STANDARDS

Weights computed from the weight of water at 4° C. weighed in air, given by the BUREAU OF STANDARDS as 8.3358 pounds per gallon.

40°	8.6859	65°	8.6431	90°	8.6088	115°	8.5744
41°	8.6837	66°	8.6418	91°	8.6074	116°	8.5730
42°	8.6816	67°	8.6405	92°	8.6061	117°	8.5717
43°	8.6792	68°	8.6391	93°	8.6047	118°	8.5703
44°	8.6776	69°	8.6377	94°	8.6033	119°	8.5689
45°	8.6751	70°	8.6363	95°	8.6017	120°	8.5675
46°	8.6731	71°	8.6349	96°	8.6004	121°	8.5661
47°	8.6711	72°	8.6336	97°	8.5991	122°	8.5648
48°	8.6692	73°	8.6322	98°	8.5978	123°	8.5635
49°	8.6673	74°	8.6309	99°	8.5965	124°	8.5620
50°	8.6654	75°	8.6295	100°	8.5950	125°	8.5606
51°	8.6636	76°	8.6281	101°	8.5936	126°	8.5593
52°	8.6618	77°	8.6266	102°	8.5923	127°	8.5579
53°	8.6603	78°	8.6253	103°	8.5909	128°	8.5565
54°	8.6586	79°	8.6240	104°	8.5895	129°	8.5552
55°	8.6571	80°	8.6226	105°	8.5882	130°	8.5538
56°	8.6555	81°	8.6212	106°	8.5868	131°	8.5524
57°	8.6540	82°	8.6198	107°	8.5854	132°	8.5507
58°	8.6526	83°	8.6184	108°	8.5840	133°	8.5497
59°	8.6511	84°	8.6170	109°	8.5826	134°	8.5483
60°	8.6496	85°	8.6157	110°	8.5813	135°	8.5469
61°	8.6483	86°	8.6144	111°	8.5800	136°	8.5455
62°	8.6469	87°	8.6130	112°	8.5785	137°	8.5442
63°	8.6456	88°	8.6115	113°	8.5771	138°	8.5425
64°	8.6446	89°	8.6101	114°	8.5758	139°	8.5412

BOILER WATER AND FLUE GASES

Water Pressures Due to Head. At 62° F. water weighs 62.355 pounds per cubic foot, or 8.3356 pounds per gallon. As the weight of water at this standard temperature is 62.355 pounds per cubic foot, the pressure exerted by a column of water may be computed as follows:—

The pressure in pounds per Sq. Ft. $= 62.355 \times$ height of column in feet

The pressure in pounds per Sq. In. $= \dfrac{62.355}{144} \times$ height of column in feet

The height which any column of water must be to produce a given pressure is found by the following formula:—

$$\text{Height of Column in feet} = \frac{\text{pressure in pounds per square foot}}{62.355}$$

$$\text{Height of Column in feet} = \frac{\text{pressure in pounds per square inch}}{\dfrac{62.355}{144}}$$

A pressure of one pound per square inch is exerted by a column of water 2.309 feet, or 27.71 inches high at 60° F.

Heating Boiler Feed Water. The saving in fuel by heating boiler feed water, utilizing waste heat, such as exhaust steam, hot drips, etc., is computed by the following formula:—

$$\text{Saving in fuel per cent} = \frac{100\,(t - t_1)}{H + (32 - t_1)}$$

Where t_1 = the temperature of feed water before heating;
t = the temperature of feed water after heating;
H = total heat above 32° per pound of steam at the boiler pressure.

By heating boiler feed water, not only is a large saving in fuel effected, but the steaming capacity of the boiler is greatly increased.

A Flue Gas Analysis is made to determine the completeness of combustion of the carbon in the fuel. From this analysis the amount and distribution of the heat loss due to imperfect combustion can be determined. The quantities determined by a flue gas analysis are the relative proportions by volume of carbon dioxide (CO_2), oxygen (O), and carbon monoxide (CO).

Heat Lost in Flue Gases. Having taken an analysis of the flue gas this loss is found as follows:

$L = 0.24\ W\ (T - t)$ where L = B. t. u. lost per pound of fuel.
W = Weight of flue gas in pounds per pound of dry fuel.
T = Temperature of flue gas and, t = boiler room temperature.
0.24 = Specific heat of flue gases.

The weight of the flue gas W is found by the formula:—

$$W = \frac{11\,CO_2 + 8O + 7\,(CO + N)}{3\,(CO_2 + CO)} \times$$ the percentage of carbon in the fuel as found from an ultimate analysis.

CO_2, O, CO and N are the percentages by volume of carbon dioxide, oxygen, carbon monoxide and nitrogen in the flue gas.

DEFINITIONS OF UNITS

One British thermal unit (B.t.u.), or heat unit as herein used=1/180 of the heat required to raise 1 lb. of water from 32 deg. to 212 deg. Fahr.
One unit of evaporation (U. E.) = heat required to evaporate 1 lb. of water at 212 deg. into steam at the same temperature = 970.4 British thermal units.
Mechanical equivalent of heat: 1 B.t.u. = 777.54 ft.-lb. or 1 ft.-lb. = 0.0012861 B.t.u.
One pound (of force) = the force exerted by gravity on 1 lb. of matter where the acceleration due to gravity is 32.1740 ft. per second; that is (very nearly), the force of gravity on 1 lb. of matter at latitude 45 deg. at the sea level.
One horsepower = 33,000 ft.-lb. per min. = 550 ft.-lb. per sec.
= 1,980,000 ft.-lb. per hour.
= 2,546.5 B.t.u. per hour = 42.44 B.t.u. per min.
= 745.7 watts = 0.7457 kilowatt.
One kilowatt = 1000 watts = 1.3410 h.p. = 3,415 B.t.u. per hour.
= 737.56 ft.-lb. per sec.
One kilowatt-hour = 1.3410 h.p.-hr. = 2,655,200 ft.-lb.
One atmosphere = 760 mm. or 29.921 in. of mercury at 32 deg. Fahr.
= 29.951 in. of mercury at 62 deg. Fahr.
= 14.6963 lb. per sq. in.
Absolute temperature (deg. Fahr.) = temperature by thermometer plus 460 deg.

WATER

SPECIFIC HEAT OF WATER.—The following table gives the specific heat of water at various temperatures.

Temperature Fahr.	Specific Heat
32° F.	1.0094
104° F.	0.9974
212° F.	1.0101

WEIGHT AND MEASUREMENT OF WATER.—One gallon of pure water at 60° Fahr. weighs 8.34 pounds

1 cubic foot of water at 32° F. .... 62.418 pounds
1 cubic foot of water at 62° F. .... 62.355 pounds
1 cylindrical foot of water .... 49.1 pounds
1 gallon of water .... 8.34 pounds at 62° F.
1 foot head of water at 62° is equal to a pressure of 0.433 pounds per square inch.
1 pound per square inch is equivalent to a head of water 2.3093 feet in height, at 62° F.
1 cubic foot of water at 32° F. contains 7.48 U. S. gallons.
1 Imperial gallon contains 277.42 cubic inches.
1 Imperial gallon weighs 10 pounds.
1 cubic inch of water weighs .036 pounds.

PRESSURE OF WATER

The pressure of water in pounds per square inch for every foot in height to 205 feet, and then by intervals to 1,000 feet head. By this table, from the pounds pressure per square inch, the feet head is readily obtained and *vice versa*.

Feet Head	Pressure per Sq. In.	Feet Head	Pressure per Sq. In.	Feet Head	Pressure per Sq. In.	Feet Head	Pressure per Sq. In.	Feet Head	Pressure per Sq. In.
1	0.43	49	21.22	97	42.01	145	62.81	193	83.60
2	0.86	50	21.65	98	42.45	146	63.24	194	84.03
3	1.30	51	22.09	99	42.88	147	63.67	195	84.47
4	1.73	52	22.52	100	43.31	148	64.10	196	84.90
5	2.16	53	22.95	101	43.75	149	64.54	197	85.33
6	2.59	54	23.39	102	44.18	150	64.97	198	85.76
7	3.03	55	23.82	103	44.61	151	65.40	199	86.20
8	3.46	56	24.26	104	45.05	152	65.84	200	86.63
9	3.89	57	24.69	105	45.48	153	66.27	201	87.07
10	4.33	58	25.12	106	45.91	154	66.70	202	87.50
11	4.76	59	25.55	107	46.34	155	67.14	203	87.93
12	5.20	60	25.99	108	46.78	156	67.57	204	88.36
13	5.63	61	26.42	109	47.21	157	68.00	205	88.80
14	6.06	62	26.85	110	47.64	158	68.43	210	90.96
15	6.49	63	27.29	111	48.08	159	68.87	215	93.13
16	6.93	64	27.72	112	48.51	160	69.31	220	95.30
17	7.36	65	28.15	113	48.94	161	69.74	225	97.46
18	7.79	66	28.58	114	49.38	162	70.17	230	99.63
19	8.22	67	29.02	115	49.81	163	70.61	235	101.79
20	8.66	68	29.45	116	50.24	164	71.04	240	103.96
21	9.09	69	29.88	117	50.68	165	71.47	245	106.13
22	9.53	70	30.32	118	51.11	166	71.91	250	108.29
23	9.96	71	30.75	119	51.54	167	72.34	255	110.46
24	10.39	72	31.18	120	51.98	168	72.77	260	112.62
25	10.82	73	31.62	121	52.41	169	73.20	265	114.79
26	11.26	74	32.05	122	52.84	170	73.64	270	116.96
27	11.69	75	32.48	123	53.28	171	74.07	275	119.12
28	12.12	76	32.92	124	53.71	172	74.50	280	121.29
29	12.55	77	33.35	125	54.15	173	74.94	285	123.45
30	12.99	78	33.78	126	54.58	174	75.37	290	125.62
31	13.42	79	34.21	127	55.01	175	75.80	295	127.78
32	13.86	80	34.65	128	55.44	176	76.23	300	129.95
33	14.29	81	35.08	129	55.88	177	76.67	310	134.28
34	14.72	82	35.52	130	56.31	178	77.10	320	138.62
35	15.16	83	35.95	131	56.74	179	77.53	330	142.95
36	15.59	84	36.39	132	57.18	180	77.97	340	147.28
37	16.02	85	36.82	133	57.61	181	78.40	350	151.61
38	16.45	86	37.25	134	58.04	182	78.84	360	155.94
39	16.89	87	37.68	135	58.48	183	79.27	370	160.27
40	17.32	88	38.12	136	58.91	184	79.70	380	164.61
41	17.75	89	38.55	137	59.34	185	80.14	390	168.94
42	18.19	90	38.98	138	59.77	186	80.57	400	173.27
43	18.62	91	39.42	139	60.21	187	81.00	500	216.58
44	19.05	92	39.85	140	60.64	188	81.43	600	259.90
45	19.49	93	40.28	141	61.07	189	81.87	700	303.22
46	19.92	94	40.72	142	61.51	190	82.30	800	346.54
47	20.35	95	41.15	143	61.94	191	82.73	900	389.86
48	20.79	96	41.58	144	62.37	192	83.17	1000	433.18

STEAM

SATURATED STEAM.—Steam that is formed in a closed vessel in contact with water is called saturated steam. It has a different density and pressure for each temperature. Dry saturated steam is steam that carries no water in suspension.

SUPERHEATED STEAM.—If more heat is added to the steam after all of the water it contains has been transferred into steam, the temperature of the steam will be greater than that of ordinary saturated steam having the same pressure. The steam is then said to be superheated. The number of degrees of temperature by which the superheated steam temperature exceeds the temperature of saturated steam at the same pressure is called the "degree of superheat."

***PRIMING.**—Saturated steam may carry a percentage of water in it. It would then be called wet saturated steam. Steam produced in boilers where the hot gases are not in contact with the surface surrounding the steam, will nearly always be "primed" or wet.

This priming or wetness may vary from about 1/10 of 1 per cent. to about 3 or 4 per cent.

ATMOSPHERIC PRESSURE.—For general engineering purposes, atmospheric pressure is considered as 14.7 pounds per square inch.

When the steam gauge of a boiler is read, this pressure indicated is above atmospheric pressure. Therefore, if "absolute pressure" is desired, 14.7 pounds must be added to the gauge reading.

FLOW OF STEAM IN MAINS.—Steam pipes and mains are usually designed to allow for short pipes, about 6000 feet per minute velocity. For medium length pipes about 5000 feet per minute. For long pipes about 4000 feet per minute.

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* Note. Priming, or passing off the steam from a boiler in "spasmodic puffs," may be caused by a concentration of sodium carbonate, sodium chloride, or sodium sulphate in solution. The sodium sulphate may be found in water from certain Southern sections and in other waters where calcium or magnesium sulphate has been precipitated with soda ash. The boiler should be frequently blown down.

CONVERSION TABLE

TABLE OF EQUIVALENT TEMPERATURES

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
—25°	—13°	50°	122°	125°	257°	200°	392°	275°	527°	350°	662°	425°	797°
—20	— 4	55	131	130	266	205	401	280	536	355	671	430	806
—15	+ 5	60	140	135	275	210	410	285	545	360	680	435	815
—10	14	65	149	140	284	215	419	290	554	365	689	440	824
— 5	23	70	158	145	293	220	428	295	563	370	698	445	833
0°	32°	75°	167°	150°	302°	225°	437°	300°	572°	375°	707°	450°	842°
5	41	80	176	155	311	230	446	305	581	380	716	455	851
10	50	85	185	160	320	235	455	310	590	385	725	460	860
15	59	90	194	165	329	240	464	315	599	390	734	465	869
20	68	95	203	170	338	245	473	320	608	395	743	470	878
25°	77°	100°	212°	175°	347°	250°	482°	325°	617°	400°	752°	475°	887°
30	86	105	221	180	356	255	491	330	626	405	761	480	896
35	95	110	230	185	365	260	500	335	635	410	770	485	905
40	104	115	239	190	374	265	509	340	644	415	779	490	914
45	113	120	248	195	383	270	518	345	653	420	788	495	923

TABLE OF VALUES FOR INTERPOLATION IN ABOVE

1°C=1.8°F	4°C= 7.2°F	7°C=12.6°F	1°F=0.55°C	4°F=2.22°C	7°F=3.88°C
2 =3.6	5 = 9.0	8 =14.4	2 =1.11	5 =2.77	8 =4.44
3 =5.4	6 =10.8	9 =16.2	3 =1.66	6 =3.33	9 =5.00

All decimals are exact. All decimals are repeating decimals.

PIPES

TO DETERMINE THE AREA OF A PIPE IN SQUARE INCHES.—To determine the area of a pipe in square inches, which will deliver a certain number of cubic feet in a definite time, when the velocity of flow is known, the following method may be used: Multiply the quantity of discharge in cubic feet by 144 and divide the product by the velocity of flow multiplied by the time in minutes:

$$\frac{D \times 144}{V \times T} = \text{Area in square inches.}$$

Where $D =$ Discharge in cubic feet.
$V =$ Velocity of flow in feet per minute.
$T =$ Time in minutes.

TO DETERMINE THE VELOCITY OF FLOW.—To determine the velocity of flow in feet per minute for a discharge of a definite number of gallons through a pipe of known diameter in a given number of minutes:

$$V = \frac{D}{G \times T}$$

Where $D =$ Discharge in gallons.
$G =$ number of gallons per lineal foot.
$T =$ Time in minutes.

TO DETERMINE THE VELOCITY OF FLOW IN FEET PER MINUTE FOR A PIPE TO DISCHARGE A DEFINITE NUMBER OF CUBIC FEET.—To determine the velocity of flow in feet per minute in a pipe of known diameter to discharge a given number of cubic feet:

$$V = \frac{F}{A \times T}$$

or

$$V = \frac{F \times 144}{N \times T}$$

Where $F =$ Number of cubic feet.
$A =$ Area of pipe in square feet.
$T =$ Time in minutes.
$N =$ Area of pipe in square inches.

TO DETERMINE THE APPROXIMATE DIAMETER OF A PIPE.—To determine the approximate diameter of a pipe which will deliver a given number of gallons in a definite number of minutes, the velocity being known:

$$\text{Gallons per foot} = \frac{D}{T \times V}$$

Where $D =$ Discharge per minute.
$T =$ Time in minutes.
$V =$ Velocity of feet per minute.

RELATIVE CARRYING CAPACITY OF PIPES OF VARIOUS DIAMETERS

Diam.	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	11	12
1	1.00	.48	.27	.14	.07	.05	....	....	....	....	....	....	....	....	....	....	....
1¼	2.10	1.00	.55	.29	.16	.10	.06	....	....	....	....	....	....	....	....	....	....
1½	3.70	1.80	1.00	.53	.29	.18	.11	.08	....	....	....	....	....	....	....	....	....
2	7.14	3.40	1.90	1.00	.53	.33	.21	.14	.10	....	....	....	....	....	....	....	....
2½	13.40	6.30	3.50	1.90	1.00	.63	.40	.27	.20	.15	....	....	....	....	....	....	....
3	21.40	10.30	5.70	3.00	1.60	1.00	.67	.43	.32	.23	.15	....	....	....	....	....	....
3½	....	16.10	9.00	4.70	2.50	1.50	1.00	.68	.50	.38	.23	.15	....	....	....	....	....
4	....	....	13.10	6.90	3.70	2.30	1.40	1.00	.71	.56	.34	.23	.15	....	....	....	....
4½	....	....	....	9.60	5.00	3.10	2.00	1.40	1.00	.77	.47	.31	.21	.14	.12	....	....
5	....	....	....	....	6.70	4.40	2.60	1.80	1.30	1.00	.63	.42	.28	.20	.16	.13	.10
6	....	....	....	....	....	6.50	4.30	2.90	2.10	1.60	1.00	.66	.45	.33	.26	.21	.16
7	....	....	....	....	....	....	6.50	4.40	3.20	2.40	1.50	1.00	.71	.53	.40	.32	.24
8	....	....	....	....	....	....	....	6.50	4.70	3.50	2.20	1.40	1.00	.76	.59	.47	.36
9	....	....	....	....	....	....	....	....	6.42	4.77	2.98	1.90	1.33	1.00	.79	.60	.48
10	....	....	....	....	....	....	....	....	8.30	6.30	3.90	2.50	1.70	1.28	1.00	.78	.61
11	....	....	....	....	....	....	....	....	....	8.24	5.02	3.25	2.20	1.66	1.28	1.00	.79
12	....	....	....	....	....	....	....	....	....	10.30	6.30	4.10	2.80	2.08	1.60	1.27	1.00

HEATING OR COOLING SURFACE OF PIPES AND TUBES PER FOOT AND PER INCH OF LENGTH

Diameter	Per Foot	Per Inch
Inches	Square Feet	Square Feet
1¼	.3272	.0272
1⅜	.3599	.0299
1½	.3927	.0327
1⅝	.4254	.0354
1¾	.4580	.0381
1⅞	.4908	.0409
2	.5236	.0436
2⅛	.5562	.0463
2¼	.5890	.0490
2⅜	.6218	.0518
2½	.6545	.0545
2⅝	.6872	.0572
2¾	.7199	.0599
3	.7854	.0655
3¼	.8508	.0709
3½	.9163	.0763
3¾	.9817	.0818
4	1.0472	.0872
4¼	1.1126	.0927
4½	1.1781	.0981
4¾	1.2435	.1036
5	1.3090	.1090
5¼	1.3745	.1140
5⅜	1.4072	.1173
5½	1.4390	.1200
5¾	1.5053	.1250
6	1.5708	.1309

STANDARD SIZES OF WROUGHT-IRON PIPE

Size of Pipe	Actual Outside Diameter (Inches)	Actual Inside Diameter (Inches)	External Circumference (Inches)	Length of Pipe per Square Foot of Outside Surface (Feet)	Weight per Foot of Length (Pounds)	Number of Threads per Inch of Screw
1/8"	0.405	0.270	1.272	9.434	0.243	27
1/4"	0.540	0.364	1.699	7.075	0.422	18
3/8"	0.675	0.494	2.120	5.660	0.561	18
1/2"	0.840	0.623	2.639	4.547	0.845	14
3/4"	1.050	0.824	3.299	3.637	1.126	14
1"	1.315	1.048	4.131	2.904	1.670	11 1/2
1 1/4"	1.660	1.380	5.215	2.301	2.258	11 1/2
1 1/2"	1.900	1.611	5.969	2.010	2.694	11 1/2
2"	2.375	2.067	7.461	1.608	3.667	11 1/2
2 1/2"	2.875	2.468	9.032	1.328	5.773	8
3"	3.500	3.067	10.996	1.091	7.547	8
3 1/2"	4.000	3.548	12.566	0.955	9.055	8
4"	4.500	4.026	14.137	0.849	10.728	8
4 1/2"	5.000	4.508	15.708	0.764	12.492	8
5"	5.563	5.045	17.477	0.686	14.564	8
6"	6.625	6.065	20.813	0.576	18.767	8
7"	7.625	7.023	23.954	0.501	23.410	8
8"	8.625	7.982	27.096	0.443	28.347	8

Doubling diameter increases pipe capacity four times. The friction of liquids carried in pipes increases as the square of the velocity.

CONVERSION TABLES

Conversion of United States Gallons into Litres

Gallons	0	1	2	3	4	5	6	7	8	9
	Litres	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*	*Litres*
0	0.0000	3.7853	7.5706	11.356	15.141	18.946	22.712	26.497	30.282	34.068
10	37.853	41.638	45.423	49.209	52.994	56.799	60.565	64.350	68.135	71.921
20	75.706	79.491	83.276	87.062	90.847	94.652	98.418	102.20	105.99	109.77
30	113.56	117.34	121.13	124.92	128.66	132.50	136.27	140.06	143.84	147.63
40	151.42	155.22	158.99	162.78	166.56	170.36	174.13	177.92	181.70	185.49
50	189.46	193.24	197.03	200.82	204.60	208.40	212.17	215.96	219.74	223.53
60	227.12	230.90	234.69	238.48	242.26	246.06	249.83	253.62	257.40	261.19
70	264.97	268.75	272.54	276.33	280.11	283.91	286.68	291.47	295.25	299.04
80	302.82	306.60	310.39	314.18	317.96	321.76	324.53	329.32	333.10	336.89
90	340.68	344.46	348.25	352.04	355.82	359.62	363.39	367.18	370.96	374.75
100	378.53	382.31	386.10	389.89	393.67	397.47	401.24	405.03	408.81	412.60

Conversion of Litres into United States Gallons

Litres	0	1	2	3	4	5	6	7	8	9
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*
0	0.0000	0.2642	0.5284	0.7925	1.0567	1.3209	1.5851	1.8492	2.1134	2.3776
10	2.6418	2.9060	3.1702	3.4343	3.6985	3.9627	4.2269	4.4910	4.7552	5.0194
20	5.2836	5.5478	5.8120	6.0761	6.3403	6.6045	6.8687	7.1328	7.3970	7.6612
30	7.9254	8.1896	8.4538	8.7179	8.9821	9.2463	9.5105	9.8746	10.030	10.303
40	10.567	10.831	11.095	11.360	11.624	11.888	12.152	12.416	12.680	12.945
50	13.209	13.473	13.737	14.002	14.266	14.530	14.794	15.058	15.322	15.587
60	15.851	16.115	16.379	16.644	16.908	17.172	17.436	17.700	17.964	18.229
70	18.492	18.756	19.020	19.284	19.549	19.813	20.077	20.341	20.605	20.870
80	21.134	21.398	21.662	21.926	22.191	22.455	22.719	22.983	23.247	23.512
90	23.776	24.040	24.304	24.568	24.832	25.097	25.361	25.625	25.889	26.154
100	26.418	26.682	26.946	27.210	27.475	27.739	28.003	28.267	28.531	28.796

Conversion of English Pounds into Kilograms

English Pounds	0	1	2	3	4	5	6	7	8	9
	Kilo.	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*	*Kilo.*
0	0.000	0.453	0.907	1.361	1.814	2.268	2.722	3.175	3.629	4.082
10	4.536	4.989	5.443	5.897	6.350	6.804	7.258	7.711	8.165	8.618
20	9.072	9.525	9.979	10.43	10.89	11.34	11.79	12.25	12.70	13.15
30	13.61	14.06	14.52	14.97	15.42	15.88	16.33	16.78	17.24	17.69
40	18.14	18.59	19.05	19.50	19.95	20.41	20.86	21.31	21.77	22.22
50	22.68	23.13	23.59	24.04	24.49	24.95	25.40	25.85	26.31	26.76
60	27.22	27.67	28.13	28.58	29.03	29.49	29.94	30.39	30.85	31.30
70	31.75	32.20	32.66	33.11	33.56	34.02	34.47	34.92	35.38	35.83
80	36.29	36.74	37.20	37.65	38.10	38.56	39.01	39.46	39.92	40.37
90	40.82	41.27	41.73	42.18	42.63	43.09	43.54	43.99	44.45	44.90
100	45.36	45.81	46.27	46.72	47.17	47.63	48.08	48.53	48.99	49.44

Conversion of Kilograms into English Pounds

French Kilo.	0	1	2	3	4	5	6	7	8	9
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
0	0.000	2.205	4.410	6.615	8.820	11.02	13.23	15.43	17.64	19.84
10	22.05	24.25	26.46	28.67	30.87	33.07	35.28	37.48	39.69	41.89
20	44.10	46.30	48.51	50.72	52.92	55.12	57.33	59.53	61.74	63.94
30	66.15	68.35	70.56	72.77	74.97	77.17	79.38	81.58	83.79	85.99
40	88.20	90.40	92.61	94.82	97.02	99.22	101.4	103.6	105.8	108.0
50	110.2	112.5	114.6	116.8	119.0	121.2	123.4	125.6	127.8	130.0
60	132.3	134.5	136.7	138.9	141.1	143.3	145.5	147.7	149.9	152.1
70	154.3	156.5	158.7	160.9	163.1	165.3	167.5	169.7	171.9	174.1
80	176.4	178.6	180.8	183.0	185.2	187.4	189.6	191.8	194.0	196.2
90	198.4	200.6	202.8	205.0	207.2	209.4	211.6	213.8	216.0	218.2
100	220.5	222.7	224.9	227.1	229.3	231.5	233.7	235.9	238.1	240.3

METRIC SYSTEM OF MEASURES
COMPARED WITH FEET AND INCHES
12 Inches Equal 1 Foot

Inches are divided into halves, quarters, eighths, sixteenths, thirty-seconds and sixty-fourths.

Metric Denominations		Equivalents in Feet and Inches
Myriameter..............	10,000 meters	6.2137 miles
Kilometer................	1,000 meters	0.62137 mile or 3280 10/12 feet
Hectometer..............	100 meters	328 1/12 feet
Dekameter................	10 meters	32 8/12 feet
Meter....................	1 meter	39.37 inches
Decimeter...............	1/10 of a meter	3.937 inches
Centimeter..............	1/100 of a meter	0.3937 inch
Millimeter..............	1/1000 of a meter	0.0394 inch

LINEAR MEASURE
Metric to United States Measure

Metres = Inches	Metres = Feet	Metres = Yards	Kilometers = Miles
1 = 39.37	1 = 3.28083	1 = 1.093611	1 = 0.62137
2 = 78.74	2 = 6.56167	2 = 2.187222	2 = 1.24274
3 = 118.11	3 = 9.84250	3 = 3.28033	3 = 1.86411
4 = 157.48	4 = 13.12333	4 = 4.374444	4 = 2.48548
5 = 196.85	5 = 16.40417	5 = 5.468056	5 = 3.10685
6 = 236.22	6 = 19.68500	6 = 6.561667	6 = 3.72822
7 = 275.59	7 = 22.96583	7 = 7.655278	7 = 4.34959
8 = 314.96	8 = 26.24667	8 = 8.748889	8 = 4.97096
9 = 354.33	9 = 29.52750	9 = 9.842500	9 = 5.59233

UNITED STATES TO METRIC MEASURE

Inches = Centimetres	Feet = Metres	Yards = Metres	Miles = Kilometres
1 = 2.54	1 = 0.304801	1 = 0.914402	1 = 1.60935
2 = 5.08	2 = 0.609601	2 = 1.828804	2 = 3.21869
3 = 7.62	3 = 0.914402	3 = 2.743205	3 = 4.82804
4 = 10.16	4 = 1.219202	4 = 3.657607	4 = 6.43739
5 = 12.70	5 = 1.524003	5 = 4.572009	5 = 8.04674
6 = 15.24	6 = 1.828804	6 = 5.486411	6 = 9.65608
7 = 17.78	7 = 2.133604	7 = 6.400813	7 = 11.26543
8 = 20.32	8 = 2.438405	8 = 7.315215	8 = 12.87478
9 = 22.86	9 = 2.743205	9 = 8.229616	9 = 14.48412

METRIC SYSTEM OF WEIGHTS
COMPARED WITH POUNDS AND OUNCES

Metric Denominations		Equivalents in Pounds and Ounces, Avoirdupois
Millier..................	1,000,000 grams	2204.6 pounds
Quintal..................	100,000 grams	220.46 pounds
Myriagram..............	10,000 grams	22.046 pounds
Kilogram or Kilo.........	1,000 grams	2.2046 pounds
Hectogram...............	100 grams	3.5274 ounces
Dekagram................	10 grams	0.3527 ounce

PAR VALUES OF FOREIGN COINS

(Legal standards: (*G*) = gold; (*S*) = silver)

Country	Monetary unit	Value in terms of U. S. money
Argentine (*G*)	Peso	$0.9647
Austria (*G*)	Crown	0.2026
Belgium (*G* and *S*)	Franc	0.1929
Bolivia (*G*)	Boliviano	0.3893
Brazil (*G*)	Milreis	0.5463
British Colonies in Australasia and Africa (*G*)	Pound sterling	4.8665
Canada (*G*)	Dollar	1.0000
Central American States:		
Costa Rica (*G*)	Colon	0.4653
British Honduras (*G* or *S*)	Dollar	1.0000
Guatemala (*S*)	Peso	0.4446
Honduras (*S*)	Peso	0.4446
Salvador (*S*)	Peso	0.4446
Nicaragua (*S*)	Cordoba	1.0000
Chile (*G*)	Peso	0.3649
China (*S*)	Yuan	0.4777
Colombia (*G*)	Pound	4.8665
Czechoslovakia (*G*)	Crown	0.2026
Denmark (*G*)	Crown	0.2680
Ecuador (*G*)	Sucre	0.4866
Egypt (*G*)	Pound	4.9429
Finland (*G*)	Markka	0.1929
France (*G* or *S*)	Franc	0.1929
Germany (*G*)	Mark	0.2381
Great Britain (*G*)	Pound sterling	4.8665
Greece (*G* and *S*)	Drachma	$0.1929
Haiti (*G*)	Gourde	0.9647
Hongkong (*S*)	Dollar	0.5932
Hungary (*G*)	Crown	0.2026
India (British) (*G*)	Rupee	0.3244
Jugoslavia	Crown	0.2026
Italy (*G* and *S*)	Lira	0.1929
Japan (*G*)	Yen	0.4984
Liberia (*G*)	Dollar	1.0000
Mexico (*G*)	Peso	0.4984
Netherlands (*G*)	Florin	0.4019
Norway (*G*)	Crown	0.2679
Panama (*G*)	Balboa	1.0000
Persia (*G* and *S*)	Kran	Variable
Peru (*G*)	Libra	4.8665
Philippine Islands (*G*)	Peso	0.5000
Portugal (*G*)	Escudo	1.0805
Roumania (*G*)	Leu	0.1929
Russia (*G*)	Ruble	0.5145
Santo Domingo (*G*)	Dollar	1.0000
Servia (*G*)	Dinar	0.1929
Siam (*G*)	Tical	0.3708
Spain (*G* and *S*)	Peseta	0.1929
Straits Settlement (*G*)	Dollar	0.5677
Sweden (*G*)	Crown	0.2679
Switzerland (*G*)	Franc	0.1929
Turkey (*G*)	Piaster	0.0439
Uruguay (*G*)	Peso	1.0342
Venezuela (*G*)	Bolivar	0.1929

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